DNA 6014F

OPERATION UPSHOT-KNOTHOLE

1953

United States Atmospheric Nuclear Weapons Tests
Nuclear Test Personnel Review

Prepared by the Defense Nuclear Agency as Executive Agency
for the Department of Defense

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the activities of an estimated 21,000 DOD personnel, both military and civilian, in Operation UPSHOT-KNOTHOLE, the fourth atmospheric nuclear weapons testing series, conducted in Nevada from 17 March to 4 June 1953. Operation UPSHOT-KNOTHOLE consisted of 11 nuclear events. Activities engaging DOD personnel included Exercise Desert Rock V programs, scientific and diagnostic experiments, and DOD support activities. Radiological safety criteria and procedures were established and implemented during Operation UPSHOT-KNOTHOLE to minimize participants' exposures to radioactivity.

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18. SUPPLEMENTARY NOTES (continued)

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Fact Sheet

dna

Defense Nuclear Agency
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Subject: Operation UPSHOT-KNOTHOLE

Operation UPSHOT-KNOTHOLE, the ninth series of atmospheric nuclear weapons tests, was conducted by the Atomic Energy Commission (AEC) at the Nevada Proving Ground from 17 March 1953 to 4 June 1953. The series consisted of 11 nuclear tests. One detonation was an atomic artillery projectile fired from a 280mm cannon, three were airdrops, and seven were detonated on towers, ranging from 100 to 300 feet in height. The operation involved an estimated 21,000 Department of Defense (DOD) personnel participating in observer programs, tactical maneuvers, scientific studies, and support activities. Operation UPSHOT-KNOTHOLE was intended to test nuclear devices for possible inclusion in the U.S. arsenal, to improve military tactics, equipment, and training, and to study civil defense needs.

Department of Defense Involvement

During Operation UPSHOT-KNOTHOLE, the largest DOD participation was in Exercise Desert Rock V, a program involving members of all four armed services. Exercise Desert Rock V included troop orientation and training, a volunteer officer observer program, tactical troop maneuvers, operational helicopter tests, and damage effects evaluation. Orientation and training generally included lectures and briefings on the effects of nuclear weapons, observation of a nuclear detonation, and a subsequent visit to a display of military equipment damaged by the detonation. In the volunteer officer observer program, trained staff officers calculated the effects of a nuclear detonation to determine a minimum safe distance for observing the blast; they later watched the detonation from the calculated position. Tactical maneuvers were designed to train troops and to test military tactics for the nuclear battlefield. The operational helicopter tests performed by the Marine Corps were designed to investigate the capability of helicopters and their crews to withstand a nuclear burst and its effects. The damage effects evaluation enabled the services to determine the amount of damage sustained by military vehicles and equipment at various distances from nuclear detonations.

In addition to Desert Rock activities, scientific experiments were conducted by three test groups of the Joint Test Organization (JTO). The Military Effects Group consisted of personnel from Field Command, Armed Forces Special Weapons Project (AFSWP). The Weapons Development Group comprised personnel from the Los

Alamos Scientific Laboratory (LASL) and the University of California Radiation Laboratory (UCRL), the two AEC weapons development laboratories. The Civil Effects Group was established by the Federal Civil Defense Administration to assess the effects of nuclear detonations on civilian structures and food products. Although the Military Effects Group was the only DOD-sponsored test group, DOD personnel also assisted in the experiments conducted by the other two test groups. Participants in scientific experiments placed data-collection instruments around the point of detonation before the scheduled nuclear test. They returned to the test area to recover equipment and gather data after the detonation, when the Test Director had determined that the area was safe for limited access.

During UPSHOT-KNOTHOLE, approximately 2,000 troops, primarily from the Sixth Army, were present at Camp Desert Rock to provide support services for both Exercise Desert Rock V and the JTO. These services included radiological safety, communications, medical care, transportation, security, and construction. The Radiological Safety Section was composed mainly of personnel from the 50th Chemical Service Platoon. Other support elements included men from the 505th Signal Service Group (Composite Company); Detachment 371st Evacuation Hospital; 26th Transportation Truck Battalion; Company C, 505th Military Police Battalion; and the 412th Engineer Construction Battalion.

The Air Force Special Weapons Center (AFSWC) from Kirtland Air Force Base, New Mexico, provided aircraft and pilots for delivery of the airdropped devices, preshot security sweeps, cloud sampling, cloud tracking, and aerial radiation surveys. Over 400 air and ground crew personnel at Indian Springs Air Force Base and about 2,000 at Kirtland Air Force Base participated in AFSWC operations during Operation UPSHOT-KNOTHOLE. The principal AFSWC unit was the 4925th Test Group (Atomic). Other participating units included the 4935th Air Base Squadron, the 4901st Support Wing, and the 55th Weather Reconnaissance Squadron.

Summaries of UPSHOT-KNOTHOLE Nuclear Events

The 11 UPSHOT-KNOTHOLE events are summarized in the accompanying table, and their locations are shown on the accompanying map. Shots ANNIE, NANCY, BADGER, SIMON, ENCORE, and GRABLE involved larger numbers of DOD participants than the other five shots and are described below in some detail.

Shot ANNIE, a 300-foot tower detonation, was fired with a yield of 16 kilotons at 0520 hours Pacific Standard Time on 17 March 1953 in Area 3 of Yucca Flat. The AEC designated ANNIE an "open shot," which meant that reporters were allowed to view the detonation from News Nob, 12 kilometers south of the shot-tower. In addition, 20 reporters were selected to accompany the troops to the trenches, located 3,200 meters southwest of the tower.

Exercise Desert Rock V activities at Shot ANNIE included troop maneuvers, troop orientation and indoctrination, operational helicopter tests, and damage effects evaluation. Of the 1,700 personnel involved in these projects, 1,181 troops, divided into two Battalion Combat Teams (BCTs), participated in the tactical maneuver. Unlike the maneuver troops at other UPSHOT-KNOTHOLE events who were assigned to units all over the United States, the troops at Shot ANNIE had been specifically assigned to provide support at Camp Desert Rock. After the preshot orientation and rehearsal, which were conducted before each shot with Desert Rock participation, maneuver troops observed the shot with other observers in the trenches. After the shot, the two BCTs, each preceded by a radiological safety monitor, attacked an objective located about one kilometer west of ground zero. Once they reached their objective, the troops went to the display area and inspected the displays up to the 2.5 roentgen-per-hour (R/h) radiation intensity line. This line was 460 to 640 meters from ground zero.

Besides the tactical maneuver troops, an estimated 505 personnel from various services participated in the orientation and indoctrination program, which consisted of instruction in nuclear weapons, observation of the detonation, and a postshot tour of the display areas. In addition, approximately ten Marines and three helicopters from the Helicopter Atomic Test Unit, 2d Marine Corps Provisional Atomic Exercise Brigade, participated in a test of the effects of overpressure. The helicopters were parked on the side of a hill 17 kilometers from ground zero at the time of the ANNIE detonation. About 45 minutes after the shot, the helicopters airlifted some troops from the trench area to a location two kilometers south of ground zero. The helicopters flew to the decontamination station after the exercise, which was standard procedure in the UPSHOT-KNOTHOLE helicopter tests.

For the damage effects evaluation, the 412th Engineer Construction Battalion placed barbed wire obstacles and excavated trenches, bunkers, and foxholes in the display area, which extended 3,200 meters south of ground zero. The chemical team placed film badges in the open and in the fortifications, and the 3623rd Ordnance Company placed military equipment in the display area. After the shot, the engineer team and the ordnance team returned to the display area to assess the damage to the fortifications, and the chemical team retrieved the film badges.

DOD personnel at Shot ANNIE also participated in scientific experiments and air support activities. About 300 DOD personnel were involved in projects performed by the test groups, and another 80 AFSWC personnel provided air support.

Shot NANCY, a 300-foot tower detonation, was fired with a yield of 24 kilotons at 0510 hours Pacific Standard Time on 24 March 1953 in Area 4 of Yucca Flat. A shift in wind direction at shot-time caused fallout in an area between the Desert Rock maneuver

troops and their objective, and the Shot NANCY cloud approached the troop trenches before it was carried to the west and north. The peak intensity noted at the trenches was 0.018 R/h.

At NANCY, Exercise Desert Rock V activities included troop maneuvers, the volunteer officer observer program, troop orientation and indoctrination, operational helicopter tests, and damage effects evaluation. Of the approximately 2,860 personnel involved, about 2,350 participated in the tactical troop maneuver.

The maneuver troops, divided into two BCTs, first underwent an orientation program and then observed the shot from trenches 3,660 meters south-southwest of ground zero. After the detonation, the BCTs, accompanied by radiological safety monitors, began an attack on objectives about 1,000 and 2,000 meters northwest of ground zero. As the two BCTs headed toward their objectives, the radiological safety monitors nearest ground zero reported levels of radiation approaching 2.0 R/h. As a result, one BCT was ordered to shift its advance to the west. That BCT then moved on a northwest course, away from ground zero, to avoid the radiation area. Neither BCT was able to approach closer than 460 to 640 meters to its objective. At that distance, one of the BCTs encountered a radiation intensity of 14 R/h. The troops returned to the display area, where they viewed the effects of the detonation on military equipment, field fortifications, and sheep.

The estimated 490 observers formed the next largest group of Desert Rock participants at NANCY. Observers witnessed NANCY from trenches located 3,660 meters from ground zero. After the shot, they toured the display area up to about 910 meters from ground zero. The 2.5 R/h radiation intensity line, which was the forward limit of the observers' advance, was located about 780 meters south of ground zero.

The nine volunteer officer observers at Shot NANCY positioned themselves in trenches located 2,300 meters south-southwest of ground zero. These officers were the first participants in this program. After the shot, the officers evacuated their trenches when a wind shift blew part of the cloud stem toward their position and they observed a radiation intensity reading of 0.09 R/h on their radiac instruments.

Also at Shot NANCY, an estimated nine Marines and four helicopters were involved in an operational helicopter test. Three helicopters hovered about 18 kilometers southeast of ground zero to experience the shock wave. A fourth helicopter was parked 15 kilometers southeast of ground zero. Two of these helicopters then flew toward ground zero and one attempted to land and check the radiation intensities in the area around ground zero. However, thick dust and residual radiation intensities prevented it from landing.

Finally, as part of Exercise Desert Rock V, damage effects evaluation teams compared the preshot and postshot conditions of fortifications and materiel placed in the display area before the shot by the 412th Engineer Construction Battalion and the 3623rd Ordnance Company. The medical team examined the condition of sheep that had been placed 90 to 2,740 meters from ground zero, and the chemical team retrieved film badges placed in fortifications and on stakes in the display area.

In addition to the Desert Rock projects, the scientific experiments conducted by the test groups had an estimated 400 DOD participants. An additional 80 AFSWC personnel provided air support during Shot NANCY.

Shot BADGER, a 300-foot tower detonation, was fired with a yield of 23 kilotons at 0435 hours Pacific Standard Time on 18 April 1953 in Area 2 of Yucca Flat. About 2,800 DOD personnel participated in five Desert Rock programs: troop maneuvers, volunteer officer observers, troop orientation and indoctrination, operational helicopter tests, and damage effects evaluation. The largest DOD activity at Shot BADGER was the troop maneuver, a Marine exercise which included a test of the ability of helicopters to transport troops in an attack after the employment of a nuclear weapon. The 2d Marine Corps Provisional Atomic Exercise Brigade conducted the exercise. The brigade, which included 2,167 Marines, consisted of four major units:

- Brigade Headquarters
- 1st Battalion, 8th Marine Regiment, 2d Marine Division
- 2d Battalion, 3d Marine Regiment, 3d Marine Division
- Marine Helicopter Transport Group 16 (MAG (HR) 16).

The evening before the shot, MAG (HR) 16 flew 39 helicopters to the staging area at Yucca Airstrip, 20 kilometers from ground zero, and remained there overnight. Before dawn on 18 April, the other participants had assembled to observe the shot from the trench area, located 3,660 meters south-southwest of ground zero. After the shock wave passed, the participants began the maneuver, which involved an attack on objectives 1,830 meters south-southwest of ground zero. Radiological monitoring teams preceded and accompanied the Marines. A wind shift blew the stem of the cloud over the display area and over some of the observer trenches, resulting in contamination. During the ground attack, the 1st Battalion advanced less than 460 meters before these Marines were ordered to halt because dosimeter readings exceeded 3.0 roentgens. The battalion withdrew to the trench area and was not permitted to continue the maneuver or to tour the display area. By the time the battalion had left the trench area, some Marines exceeded the allowable dose of 6.0 roentgens, with film

badge readings as high as 7.1 roentgens. The 2d Battalion reached its objective and toured the display area.

The helicopter airlift began 11 minutes after the shot. Two pathfinder helicopters preceded the other helicopters to measure radiation intensities near the objectives. The remaining 37 helicopters flew one Marine company to the area of the objectives. After arriving at the objectives, the Marines toured the display area.

Also at Shot BADGER, six Army and six Marine Corps officers took part in the volunteer officer observer program. These observers witnessed the shot from a trench 1,830 meters from ground zero. Because radiation intensities in the trench after the shot were between 30 and 50 R/h, the officers evacuated this area. They walked to a road about 180 meters west of the trenches, where they met vehicles which took them to the main trench area, 3,660 meters from ground zero. About 590 other observers, drawn from all the armed services, witnessed the shot from the main trench area, walked to the display area, and there inspected the equipment and animals up to the display located 910 meters from ground zero.

In the operational helicopter test at BADGER, four helicopters were airborne at shot-time. Two helicopters were about 14 kilometers southeast of the shot, flying toward ground zero. Two others were hovering at a point 13 kilometers southeast of ground zero. After the shot, the helicopters followed different flight paths toward ground zero and landed at different points determined by radiological conditions in the area. Two of the helicopters encountered radiation intensities greater than 50 R/h before they could take evasive action.

For the Desert Rock damage effects evaluation, the Sixth Army and the Marine Corps established displays at various distances from ground zero. The Marine Corps display consisted of extensive arrays of field equipment and uniformed mannequins, while the Army display included animals and emplacements such as bunkers, trenches, and foxholes. Army personnel placed test animals and dosimetry instruments in these emplacements to evaluate shielding effectiveness. After the shot, Army and Marine Corps personnel returned to the display area to assess the effects of the detonation.

In addition to the Desert Rock participants at Shot BADGER, another 360 DOD personnel participated in scientific projects conducted by the three JTO test groups. An additional 125 AFSWC personnel provided air support.

Shot SIMON, a 300-foot tower detonation, was fired at 0430 hours Pacific Standard Time on 25 April 1953 in Area 1 of Yucca Flat. The SIMON device produced a nuclear yield of 43 kilotons, significantly larger than expected. Because the wind shifted at

the time of detonation, radiation levels in the Desert Rock trench area were higher than anticipated. For the first time in the history of nuclear testing, the Test Director established offsite roadblocks. These were placed on U.S. Highway 91 between Las Vegas and Alamo, Nevada, and on U.S. Highway 93 between Las Vegas and St. George, Utah.

At SIMON, Exercise Desert Rock V activities involved more than 3,000 personnel in tactical troop maneuvers, troop observer and volunteer officer observer programs, operational helicopter tests, and damage effects evaluation.

The tactical troop maneuver, the largest Desert Rock program at SIMON, engaged 2,450 Army personnel. The exercise, designed to provide realistic combat training under the conditions of a nuclear battlefield, was preceded by an orientation and rehearsal. The exercise itself consisted of observing the shot, conducting a ground attack, and inspecting the display areas. For the attack, troops were divided into two BCTs, which were to capture an objective about 750 meters west of ground zero. Two radiological monitoring teams preceded the troops to the objective and display areas, and additional monitors accompanied each BCT during the attack. The BCT to the east, which was closer to ground zero, was halted 1,830 meters from ground zero when the monitors detected radiation intensities of 2.5 R/h. The other BCT, approaching on the west, continued to advance and presumably reached the objective. After the ground attack, troops viewed the display area south of ground zero. Because SIMON produced more widespread contamination than most of the previous UPSHOT-KNOTHOLE shots, several displays were inaccessible; forward movement was halted at the 1,830-meter display line, where the radiation intensity was near the limit of 2.5 R/h.

The troop observer program involved an estimated 550 observers drawn from all of the armed services. After an extensive preshot orientation, the observers viewed the shot from trenches 3,660 meters south of ground zero. They then toured the display area, approaching as close as 1,830 meters from ground zero before walking back to the trenches.

Seven Army officers and one Navy officer participated in the volunteer observer program at Shot SIMON. These volunteers chose to occupy trenches 1,830 meters from ground zero. Seconds after the burst, one officer measured a radiation intensity of 100 R/h, which dropped to about 20 to 25 R/h within one minute. As the volunteers left the trenches and walked away from ground zero, radiation levels steadily declined, except when the officers stopped to tour the display area. The group walked about 400 meters before they were met by trucks and driven to the main trench area.

Elements of the 2d Marine Corps Provisional Atomic Exercise Brigade conducted the operational helicopter test at Shot SIMON. At shot-time, three Marine helicopters were near Yucca Lake Airstrip, southeast of the detonation. Two of these helicopters were hovering 11 kilometers from ground zero, while the other, about 17 kilometers from ground zero, was proceeding toward the shot. After the shock wave passed, all helicopters flew to the shot area. One skirted the SIMON dust column, encountering radiation intensities of 50 R/h before completing evasive action. Another landed about 1,830 meters west of ground zero, where a radiation monitor walked to a location about 870 meters from ground zero and noted intensities of 10 R/h about 30 minutes after the shot. The third helicopter flew around the upwind side of the dust column and landed 2,000 meters northwest of ground zero.

For the damage effects evaluation, personnel from the 412th Engineer Construction Battalion and the 3623rd Ordnance Company prepared a display area 230 to 3,200 meters south-southeast of ground zero. Equipment, sheep, and film badges were placed in fortifications and in the open. After the shot, engineer and ordnance teams inspected equipment and fortifications to assess the damage caused by the detonation. A medical team retrieved the sheep, and a chemical team retrieved the film badges for analysis.

In addition to the Desert Rock participants, an estimated 400 DOD personnel participated in scientific projects conducted by the test groups at Shot SIMON. An additional 120 AFSWC participants provided air support.

Shot ENCORE, an airdropped nuclear device, had a yield of 27 kilotons. A B-50 from Kirtland Air Force Base delivered the ENCORE device, which was detonated 2,423 feet above Area 5 of Frenchman Flat at 0830 hours Pacific Daylight Time on 8 May 1953. The bomb was off-target by 250 meters. Shot ENCORE was a military effects test, and the Military Effects Group conducted many projects, involving about 720 DOD personnel. Perhaps another 40 took part in activities of the Weapons Development Group and the Civil Effects Group.

Although the scientific activities at ENCORE were extensive, even more DOD personnel were involved in the Desert Rock activities at the shot. More than 3,000 individuals took part in observer programs, troop maneuvers, operational helicopter tests, and damage effects evaluation. Desert Rock troop maneuvers, the largest single program conducted at ENCORE, involved about 2,475 men. Participants were organized into two BCTs, composed of provisional units from the First, Third, and Fourth Armies and from individual Air Force units.

For several days before the shot, maneuver troops attended classes and practiced their shot-day activities. They observed

the shot with the other troops in trenches 9,400 meters from the intended ground zero. The trenches were far enough from the shot that troops and other observers were allowed to rise and look at the fireball before the arrival of the shock wave, a change from previous policy.

After the shot, the two BCTs began the ground assault on two objectives, about 5,000 meters south-southwest and 1,400 meters south-southeast of ground zero. While the ground troops were marching from the trenches to the objectives, seven H-19 helicopters were airlifting one 30-man platoon from each BCT to the closer objective. The first group to arrive at that objective was a pathfinder team, which included a radiological safety monitor. This monitor took a reading of 0.26 R/h about one hour after the detonation in the vicinity of ground zero. By 1045 hours, the ground troops had secured both objectives. After spending about seven hours in the forward area, the troops returned to Camp Desert Rock.

Desert Rock observers, including representatives from each of the armed services, watched Shot ENCORE from trenches 9,400 meters from the intended ground zero and then toured the equipment display area. They spent about five hours and 20 minutes at the test site.

For the Marine Corps operational helicopter test, four HRS helicopters were tested, each operated by a crew of three from the 2d Marine Corps Provisional Atomic Exercise Brigade. At shot-time, three helicopters were 20 kilometers from ground zero at a height of 400 feet, while the fourth was hovering ten feet above the ground at a point 15.5 kilometers from ground zero. After the shock wave passed, two helicopters returned to Camp Desert Rock. The other two flew to a position 1,000 meters south of ground zero and landed briefly to allow monitors to survey the immediate area. The radiation levels that they measured 20 to 30 minutes after shot-time did not exceed 1.4 R/h.

For the Desert Rock damage effects evaluation, the 412th Engineer Construction Battalion excavated bunkers, trenches, and foxholes and built two sections of bridging. The 3623rd Ordnance Company placed equipment in the display area, which extended 3,200 meters to the southeast of ground zero. In addition, a medical evaluation team placed sheep in the area the day before the shot, and a chemical team placed film badges in the fortifications. After the shot, evaluation teams entered the display area to assess damage and to retrieve the animals and film badges for analysis.

In addition to test group and Desert Rock participants at Shot ENCORE, about 80 AFSWC personnel, including the crew for the airdrop mission, provided air support.

Shot GRABLE, the tenth test of Operation UPSHOT-KNOTHOLE, was detonated with a yield of 15 kilotons at 0830 hours Pacific

Daylight Time on 25 May 1953. A 280mm cannon fired the atomic artillery projectile, which detonated 524 feet above Area 5 (Frenchman Flat). GRABLE was the only nuclear device fired from a cannon during the test series. The Artillery Test Unit from the Artillery Center, Fort Sill, Oklahoma, fired the cannon. Like Shot ENCORE, Shot GRABLE had extensive test group activities; an estimated 650 DOD personnel participated in the Military Effects Group projects. DOD personnel also assisted in Weapons Development Group and Civil Effects Group projects.

Although the scientific program was extensive, many more DOD personnel were involved in the Desert Rock exercises. More than 2,600 exercise troops and over 700 observers participated in GRABLE. Observers, including members of each of the armed services, witnessed the shot from trenches 4,570 meters west of ground zero. After the shot, observers were to inspect the equipment display area, but because of a dust storm, they were unable to approach closer than 1,370 meters to ground zero.

After observing the shot with other Desert Rock participants, the exercise troops were to attack two objectives located 2,400 meters southeast of ground zero and 2,800 meters east-southeast of ground zero. High winds and dust forced the troops to turn back about an hour after the attack began, although some troops did approach as close as 700 meters to the south of ground zero and were subsequently able to view the equipment display up to 450 meters from ground zero.

For the damage effects evaluation at GRABLE, the 412th Engineer Construction Battalion excavated trenches, bunkers, and foxholes and constructed sections of bridging in the display area southeast of ground zero. The 3623rd Ordnance Company also placed military equipment in the area. Army personnel placed sheep and dosimetry instruments in these fortifications for use in medical and shielding evaluations. After the shot, engineer, ordnance, chemical, medical, and quartermaster teams evaluated the damage to equipment, animals, and fortifications. A veterinary officer and technician evaluated the effects of the detonation on the sheep, and a chemical team retrieved dosimetry instruments.

In addition to the test group and Desert Rock participants, about 70 AFSWC crew members provided air support.

Safety Standards and Procedures

Exercise Desert Rock V, the JTO, and AFSWC each developed its own organization and procedures for ensuring the safety of its members. Based on safety criteria established by the AEC, the radiological safety plans developed by each organization were designed to minimize individual exposures to ionizing radiation while allowing participants to accomplish their missions.

During UPSHOT-KNOTHOLE, the safety of Desert Rock participants was the responsibility of the Army. Subject to AEC approval, the Office, Chief of Army Field Forces (OCAFF), set the external gamma radiation exposure criterion for Desert Rock V troops as a maximum of 6.0 roentgens during Operation UPSHOT-KNOTHOLE, with no more than 3.0 roentgens of prompt radiation. To protect Desert Rock participants from the thermal and blast effects of nuclear detonations, OCAFF also established exposure limits for blast pressure and thermal radiation:

- Five pounds per square inch of overpressure
- One calorie per square centimeter of thermal radiation.

Based on these exposure limits and the mode of delivery, OCAFF set minimum distances from ground zero for the positioning of Desert Rock troops and observers.

In addition, OCAFF authorized a special volunteer observer program for Exercise Desert Rock V. Small groups of officer volunteers were positioned in trenches closer to ground zero than the standard distances. The exposure limits for this special program were:

- Ten roentgens of gamma radiation, with no more than five roentgens of prompt radiation per test, and a total of no more than 25 roentgens for the exercise
- Eight pounds per square inch of overpressure
- One calorie per square centimeter of thermal radiation.

The Test Manager was responsible for the radiological safety of all JTO personnel at the Nevada Proving Ground and individuals residing within 320 kilometers of the test site. Onsite radiological safety operations were performed by the AFSWP Radiological Safety Support Unit, composed of Army personnel from Fort McClellan, Alabama, and directed by AFSWP. The Radiological Safety Support Unit worked within guidelines recommended by the AEC, Division of Biology and Medicine, and accepted by the Test Manager. An exposure limit of 3.9 roentgens of gamma radiation for the series was established for personnel involved in JTO activities. Since Operation UPSHOT-KNOTHOLE lasted almost 12 weeks, this limit approximated the then-current occupational exposure limit of 3.9 roentgens for each 13-week period recommended by the National Committee on Radiation Protection and the International Commission on Radiological Protection.

AFSWC was responsible for the radiation protection of its units. The AFWSC exposure limit was 3.9 roentgens of gamma radiation for the entire operation, unless otherwise specified.

Although the missions of Desert Rock, the JTO, and AFSWC required different types of activities and separate radiation protection plans and staffs, the general procedures were similar:

- Orientation and training - preparing radiological monitors for their work and familiarizing participants with radiological safety procedures
- Personnel dosimetry - issuing and developing film badges for participants and evaluating gamma radiation exposures recorded on these badges
- Use of protective equipment - providing clothing, respirators, and other protective equipment
- Monitoring - performing radiological surveys and controlling access to radiation areas
- Briefing - informing observers and project personnel of radiological conditions in the test area
- Decontamination - detecting and removing contamination from personnel and equipment.

Radiation Exposures at UPSHOT-KNOTHOLE

As of January 1982, the military services had identified by name 11,277 of the estimated 21,000 DOD participants at Operation UPSHOT-KNOTHOLE. Film badge data are available for 2,003 of these participants, as shown in the "Summary of Dosimetry for Operation UPSHOT-KNOTHOLE" table. While film badge data for individual Desert Rock participants are generally not available, dosimetry information is available for the volunteer officer observers, who participated at Shots NANCY, BADGER, and SIMON. Each volunteer observer wore a pocket dosimeter and at least one film badge. Film badge records show that the nine volunteer officer observers at Shot NANCY had exposures between 0.3 and 0.79 roentgens. The 12 officer observers at Shot BADGER had exposures ranging from 5.2 to 9.5 roentgens. At Shot SIMON, the eight volunteers had exposures of 9.5 to 17.5 roentgens; seven of these exposures exceeded the 10.0 roentgen shot limit. One of the volunteer observers witnessed all three shots. His total gamma dose for Shots NANCY, BADGER, and SIMON was 26.6 roentgens.

Because the volunteer officer observers were relatively close to Shots NANCY, BADGER, and SIMON, the potential existed for exposure to prompt gamma and neutron radiation. The calculated mean neutron doses for the volunteer observers have been reconstructed as 0.63 roentgens for Shot NANCY; 2.4 roentgens for Shot BADGER; and 28 roentgens for Shot SIMON. Because the exposures of the volunteer officers resulted from a unique situation, their doses are not included in the "Summary of Dosimetry" table.

SUMMARY OF OPERATION UPSHOT-KNOTHOLE EVENTS (1953)

Shot	ANNIE	NANCY	RUTH	DIXIE	RAY	BADGER	SIMON	ENCORE	HARRY	GRABLE	CLIMAX
Sponsor	LASL	LASL	UCRL	LASL	UCRL	LASL	LASL	DOD LASL	LASL	DOD LASL	LASL
Planned Date	17 March	24 March	31 March	6 April	18 April	11 April	25 April	7 May	2 May	21 May	31 May
Actual Date	17 March	24 March	31 March	6 April	11 April	18 April	25 April	8 May	19 May	25 May	4 June
Local Time*	0520	0510	0500	0730	0445	0435	0430	0830	0505	0830	0415
NPG Location	Area 3	Area 4	Area 7	Area 7	Area 4	Area 2	Area 1	Area 5	Area 3	Area 5	Area 7
Type	Tower	Tower	Tower	Airdrop	Tower	Tower	Tower	Airdrop	Tower	280 mm Cannon	Airdrop
Height of Burst (Feet)†	300	300	300	6,020	100	300	300	2,423	300	524	1,334
Yield (Kilotons)	16	24	0.2	11	0.2	23	43	27	32	15	61

*Pacific Standard Time for Shots ANNIE through SIMON; Pacific Daylight Time for Shots ENCORE through CLIMAX

†Altitudes are measured from mean sea level, while heights are measured from the ground
All vertical distances are given in feet

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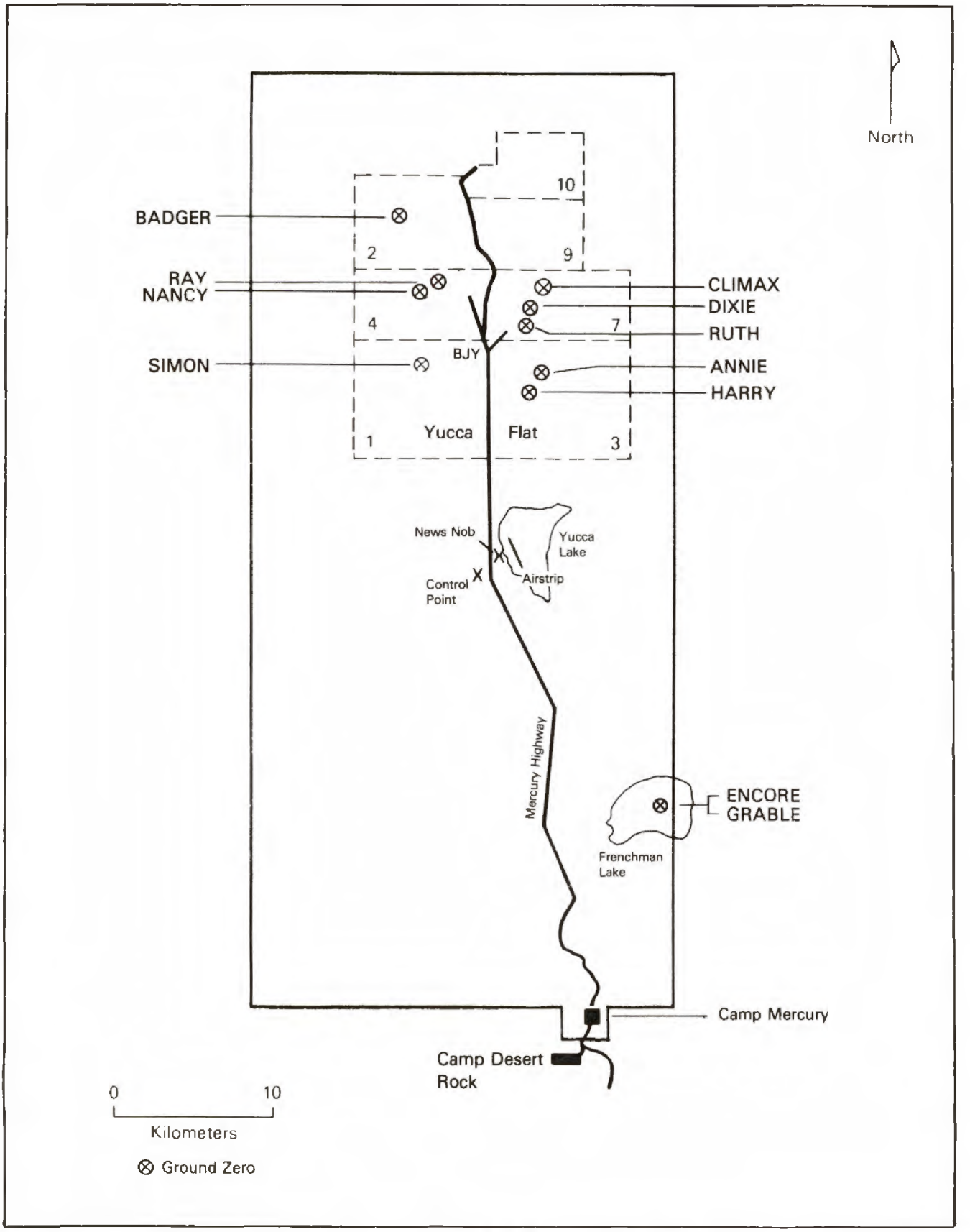

NEVADA PROVING GROUND SHOWING GROUND ZEROS
FOR OPERATION UPSHOT-KNOTHOLE

SUMMARY OF DOSIMETRY FOR OPERATION UPSHOT-KNOTHOLE AS OF JANUARY 1982*

Service	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Gamma Exposure (Roentgens)					Number of Personnel with Zero Gamma Exposure**	Average Gamma Exposure (Roentgens)	Maximum Gamma Exposure (Roentgens)
			<.1	.1-1.0	1.0-3.0	3.0-5.0	5.0+			
Army	7,445	469	163	113	73	101	19	95	1.555	16.8
Navy	504	348	125	106	74	25	18	65	1.161	14.1
Marine Corps	2,286	144	41	10	31	52	10	33	0.654	17.5
Air Force	757	757	399	233	71	33	21	232	2.174	7.7
Scientific Personnel, Contractors, and Affiliates	222	222	96	79	42	2	3	45	0.638	7.8
Service Unknown***	63	63	31	15	14	3	0	21	0.644	3.7
Total	11,277	2,003	855	556	305	216	71	491	1.061	

* Gamma exposures for the volunteer officer observers are not included because of the unique circumstances surrounding these exposures.

** The number of personnel in this column is also represented in the <.1 Gamma Exposure column.

*** Film badge data are available, but service affiliation is not.

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PREFACE

Between 1945 and 1962, the U.S. Government, through the Manhattan Engineer District and its successor agency, the Atomic Energy Commission (AEC), conducted 235 atmospheric nuclear weapons tests at sites in the southwestern United States and in the Pacific and Atlantic Oceans. In all, an estimated 220,000 Department of Defense (DOD) participants, both military and civilian, were present at the tests. Of these, approximately 90,000 were present at the atmospheric nuclear weapons tests conducted at the Nevada Proving Ground (NPG),* northwest of Las Vegas, Nevada.

In 1977, 15 years after the last above-ground nuclear weapons test, the Center for Disease Control+ noted a possible leukemia cluster among a small group of soldiers present at Shot SMOKY, one test of Operation PLUMBBOB, the series of atmospheric nuclear weapons tests conducted in 1957. Since that initial report by the Center for Disease Control, the Veterans Administration has received a number of claims for medical benefits from former military personnel who believe their health may have been affected by their participation in the program.

In late 1977, DOD began a study to provide data to both the Center for Disease Control and the Veterans Administration on potential exposures to ionizing radiation among the military and civilian personnel who had participated. DOD organized an effort to:

- Identify DOD personnel who had taken part in the atmospheric nuclear weapons tests

*Renamed the Nevada Test Site in 1955

+The Center for Disease Control is part of the U.S. Department of Health and Human Services, formerly the U.S. Department of Health, Education, and Welfare.

- Determine the extent of the participants' exposure to ionizing radiation
- Provide public disclosure of information concerning participation by DOD personnel in the atmospheric nuclear weapons tests.

This report on Operation UPSHOT-KNOTHOLE is based on the military and technical documents associated with each of the atmospheric nuclear weapons tests.

METHODS AND SOURCES USED TO PREPARE THIS VOLUME

The Defense Nuclear Agency compiled information for this volume from available documents that record the military operations and scientific activities performed during Operation UPSHOT-KNOTHOLE, the series of atmospheric nuclear weapons tests conducted in 1953. These records, most of which were developed by individuals and organizations participating in the UPSHOT-KNOTHOLE Series, are kept in over three dozen document repositories throughout the United States.

In compiling information for this report, teams of historians, health physicists, radiation specialists, and information analysts canvassed document repositories known to contain materials on atmospheric nuclear weapons tests conducted in the southwestern United States. These repositories include armed services libraries, Government agency archives and libraries, Federal repositories, and libraries of scientific and technical laboratories. The teams examined classified and unclassified documents containing information on DOD participation in Operation UPSHOT-KNOTHOLE, recorded relevant information concerning the activities of DOD personnel, and catalogued the data sources in an automated data base to allow cross-referencing and retrieval. Many of the documents pertaining specifically to DOD involvement during UPSHOT-KNOTHOLE were found in the Defense Nuclear Agency Technical Library, the Modern Military Branch of

the National Archives, the Nevada Operations Office of the Department of Energy, and the Office of Air Force History.

Gathering data for this study presented a variety of challenges. Many different military and civilian organizations were involved in developing and storing records related to Operation UPSHOT-KNOTHOLE. Each branch of the armed services and each civilian organization had its own system of recording information. Much material was not retained because it was not considered important at the time. In addition, some records have been lost or destroyed over the years. Other records have been transferred from one repository to another, and accounts of the transfer of documents are not always available.

In most cases, the surviving historical documentation of activities conducted during Operation UPSHOT-KNOTHOLE addresses test specifications and technical information, rather than the personnel data critical to the study undertaken by DOD. The available historical documentation sometimes has inconsistencies in vital facts. Efforts have been made to resolve the inconsistencies wherever possible, or otherwise to bring them to the attention of the reader. For example, the Armed Forces Special Weapons Project (AFSWP) documents do not always refer to project titles and agencies in the same way. To make this information as uniform as possible, these reports on UPSHOT-KNOTHOLE use weapons test report titles for each project. Information concerning the planned and actual dates and yields of test detonations is taken from the Department of Energy, Announced United States Nuclear Tests, July 1945 through 1979 (NVO-209). Other data on the tests, concerning fallout patterns, meteorological conditions, and cloud dimensions, are taken from DNA 1251-1, Compilation of Local Fallout Data from Test

Detonations 1945-1962, volume 1, except in instances where more specific information is available elsewhere (81; 103).*

For several of the Exercise Desert Rock and test organization projects discussed in this volume, the only documents available are the Sixth Army Desert Rock operation orders and the Test Director's Schedule of Events from "Operation Order 1-53." These sources detail the plans developed by DOD and AEC personnel prior to the UPSHOT-KNOTHOLE Series; they do not necessarily describe the operations as they were actually conducted at the NPG. Although some of the after-action documents, such as the weapons test reports for AFSWP, summarize the projects performed during the UPSHOT-KNOTHOLE Series, they do not always supply shot-specific information. In the absence of shot-specific after-action reports, projects are described according to the way they were planned. The references indicate whether the description of activities is based on the schedule of events, operation orders, or after-action reports.

ORGANIZATION OF UPSHOT-KNOTHOLE SERIES REPORTS AND THIS VOLUME ON OPERATION UPSHOT-KNOTHOLE

This volume details participation by DOD personnel in Operation UPSHOT-KNOTHOLE, the fourth atmospheric nuclear weapons testing series conducted at the NPG. Four other publications address DOD activities during the UPSHOT-KNOTHOLE Series:

- Multi-shot volume: Shots ANNIE to RAY, the First Five Tests of the UPSHOT-KNOTHOLE Series
- Shot volume: Shot BADGER
- Shot volume: Shot SIMON

*All sources cited in the text are listed alphabetically and numbered in the Bibliography at the end of this volume. The number given in the text is the number of the source document in the Bibliography.

- Multi-shot volume: Shots ENCORE to CLIMAX, the Final Four Tests of the UPSHOT-KNOTHOLE Series.

The series volume describes those dimensions of Operation UPSHOT-KNOTHOLE that apply to the series as a whole, such as historical background, organizational relationships, and radiological safety procedures. In addition, it addresses the overall objectives, describes the geographic layout of the NPG, and contains a bibliography of all works consulted in the preparation of the five Operation UPSHOT-KNOTHOLE reports. The single- and multi-shot volumes, on the other hand, contain none of this general information on Operation UPSHOT-KNOTHOLE. The two single-shot volumes describe DOD participation in Shots BADGER and SIMON. These two events have been treated in separate volumes because they included Exercise Desert Rock maneuvers involving large numbers of DOD personnel. The two multi-shot volumes combine shot-specific descriptions for several nuclear events. The shot and multi-shot volumes contain bibliographies only of the sources referenced in each of those texts. Descriptions of activities concerning any particular shot in the UPSHOT-KNOTHOLE Series, whether the shot is addressed in a single-shot volume or in a multi-shot volume, may be supplemented by the general radiological safety and organizational information contained in this volume.

This volume is divided into six chapters. Chapter 1 provides background information about Operation UPSHOT-KNOTHOLE, including an explanation of the historical context of the series, a description of the NPG, a summary and comparison of the 11 events in the series, and a summary of the activities of DOD participants. Chapter 2 describes the Joint Test Organization and Exercise Desert Rock, the two groups with major DOD participation at Operation UPSHOT-KNOTHOLE. It defines the responsibilities of each group in planning, administering, and supporting the various nuclear test events and in conducting

other activities in conjunction with those tests. Chapter 3 discusses the Exercise Desert Rock V military maneuvers conducted during Operation UPSHOT-KNOTHOLE, and chapter 4 describes other DOD activities. Chapter 4 also summarizes training activities, scientific experiments, and support missions conducted by DOD personnel. Chapters 3 and 4 define the objectives of the activities, describe the planned and actual procedures, and indicate at which shots the programs occurred. Chapter 5 describes the radiological safety criteria and procedures in effect during Operation UPSHOT-KNOTHOLE for each of the DOD groups with significant participation. Chapter 6 is a study of the results of the radiation protection program during Operation UPSHOT-KNOTHOLE, including an analysis of film badge readings for DOD personnel.

The information in this report is supplemented by the Reference Manual: Background Materials for the CONUS Volumes. This volume summarizes the basics of radiation physics, radiation health concepts, exposure criteria, and measurement techniques, as well as listing acronyms and terms used in the reports addressing nuclear test events in the continental United States.

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LIST OF ABBREVIATIONS AND ACRONYMS

The following abbreviations and acronyms are used in this volume:

AEC	Atomic Energy Commission
AFB	Air Force Base
AFSWC	Air Force Special Weapons Center
AFSWP	Armed Forces Special Weapons Project
AWS	Air Weather Service
BCTs	Battalion Combat Teams
BJY	BUSTER-JANGLE "Y"
DOD	Department of Defense
EG&G	Edgerton, Germeshausen, and Grier, Incorporated
FCDA	Federal Civil Defense Administration
HumRRO	Human Resources Research Office
IBDA	Indirect Bomb Damage Assessment
JTO	Joint Test Organization
LASL	Los Alamos Scientific Laboratory
LVTs	Landing Vehicles Tracked
NPG	Nevada Proving Ground
OCAFF	Office, Chief of Army Field Forces
REECo	Reynolds Electrical and Engineering Company
R/h	Roentgen per hour
SAC	Strategic Air Command
TAC	Tactical Air Command
UCRL	University of California Radiation Laboratory
UTM	Universal Transverse Mercator
2d MCPAEB	Second Marine Corps Provisional Atomic Exercise Brigade

CHAPTER 1

INTRODUCTION

Operation UPSHOT-KNOTHOLE was the series of atmospheric nuclear weapons tests conducted within the continental United States from 17 March 1953 to 4 June 1953. The series consisted of 11 nuclear tests and involved an estimated 21,000 DOD personnel participating in observer programs, tactical maneuvers, military effects studies, and scientific experiments. It was intended to test nuclear weapons for possible inclusion in the defense arsenal, to improve military tactics, equipment, and training, and to enhance the understanding of Civil Defense requirements in the United States.

The purpose of this volume is to summarize information on organizations, procedures, and activities of DOD personnel in the UPSHOT-KNOTHOLE Series. This chapter introduces Operation UPSHOT-KNOTHOLE with background information on:

- The international and domestic situation at the time of the UPSHOT-KNOTHOLE tests
- The establishment of Operation UPSHOT-KNOTHOLE
- NPG facilities
- The 11 individual nuclear events
- DOD participation at this test series.

The information provides a basis for understanding the nature and extent of DOD participation discussed in more detail in this volume and in the UPSHOT-KNOTHOLE shot and multi-shot volumes.

1.1 INTERNATIONAL AND DOMESTIC CONDITIONS THAT INFLUENCED OPERATION UPSHOT-KNOTHOLE

Operation UPSHOT-KNOTHOLE was planned and conducted to develop, diversify, and strengthen the nuclear arsenal of the

United States. From the conclusion of World War II, the Nation's strategic defense rested largely upon its ability to deter attack and general war by the threat of nuclear retaliation. The reliance on nuclear weapons increased in 1949 when the Soviet Union first detonated a nuclear device and the United States lost its monopoly on nuclear firepower. A new defense policy evolved in the early 1950s as two additional factors challenged the military's capability to defend American interests and to protect its allies during limited hostilities:

- The protracted commitment of U.S. ground forces to the Korean peninsula
- The inability of the United States' European allies to develop effective military capabilities.

In both cases, the United States experienced difficulties because of limited manpower in uniform, emphasizing the need for a defense policy based not on large standing armies, but on new technological advances, particularly in nuclear weapons.

The Chairman of the Atomic Energy Commission strongly advocated the development of nuclear devices for tactical purposes. Describing the prospects for new types of nuclear weapons, the AEC Chairman stated in 1951:

> What we are working toward here is a situation where we will have atomic weapons in almost as complete a variety as conventional ones....This would include artillery shells, guided missiles, torpedoes, rockets and bombs for ground-support aircraft....We could use an atomic bomb today in a tactical way against enemy troops in the field, against military concentrations near battle areas and against other vital military targets without risk to our own troops. We are steadily increasing, through our technological and production progress, the number of situations in which atomic weapons can be effectively employed in battle areas (237).

While working toward this end, the government attempted to inform the American public about the use of nuclear weapons to

halt aggression without simultaneously destroying large urban centers and populations. Thus, Shot ANNIE, the first detonation of the UPSHOT-KNOTHOLE Series, was a highly publicized event.

After witnessing a nuclear test event, four members of the Joint Congressional Atomic Energy Committee told the press: "We were impressed by the finite ... nature of a single atomic blast. The explosion yesterday morning could not by itself have performed miracles" (208). Committee members indicated that the significant advantage in firepower which the new weapons gave ground units would not eliminate the need to follow established principles of movement and position. It was essential that military units become familiar with the new weapons and their special characteristics. The best way to accomplish this was through realistic field exercises (208).

Implementation of this defense policy required the development of various nuclear weapons and the training of personnel in the use of weapons. For the strategic deterrent against general war or overt aggression, Air Force Strategic Air Command aircraft had to be equipped with suitable nuclear weapons. Should limited aggression threaten a U.S. ally where ground intervention was called for, U.S. military forces needed to be trained in the tactical employment of nuclear weapons. The UPSHOT-KNOTHOLE testing addressed both the strategic and tactical considerations of American foreign policy.

1.2 ESTABLISHMENT OF THE UPSHOT-KNOTHOLE SERIES

UPSHOT-KNOTHOLE, conducted in the spring of 1953, was planned as two separate weapons testing programs: Operation UPSHOT and Operation KNOTHOLE. In October 1951, the Chief of the Armed Forces Special Weapons Project, located in Washington, D.C., recommended to the Joint Chiefs of Staff that a large military effects test be conducted in the spring of 1953 at the

Nevada Proving Ground. The objective was to obtain general weapons effects information to supplement the data obtained at the 1951 Operation GREENHOUSE weapons testing series conducted in the Pacific. The effects of nuclear detonations on military equipment as well as on structures and other targets of military significance were of specific interest. In December 1951, the Joint Chiefs of Staff approved the recommendation, subject to a future determination concerning the nature and number of military effects tests. DOD designed the code name of KNOTHOLE to this operation, scheduled to begin on 1 April 1953 (98).

During April 1952, at the height of the TUMBLER-SNAPPER weapons testing series, the armed services submitted project recommendations to the Chief of AFSWP. He then reviewed these proposals to eliminate duplication and to ensure that all proposals were technically sound. After many conferences and discussions with the armed services, the Chief of AFSWP formulated plans for the test program. In May 1952, he submitted these plans for review to the DOD Research and Development Board. An ad hoc panel of the Research and Development Board studied the plans and suggested modifications to reduce cost. After further review by AFSWP and the armed services, construction for Operation KNOTHOLE began in the Frenchman Flat area of NPG during mid-December 1952 (70; 98).

While DOD was devising projects for Operation KNOTHOLE, the AEC was planning a nuclear weapons testing series to follow Operation IVY, scheduled for the Pacific in the fall of 1952. This testing series was to be designated Operation UPSHOT, and the earliest test date was set for the spring of 1953 (70).

With Operation UPSHOT scheduled for the spring of 1953, DOD accelerated its planning for Operation KNOTHOLE so that arrangements for the AEC and DOD tests could be coordinated. In June 1952, DOD and AEC agreed to conduct the spring 1953 tests as a combined operation, designated UPSHOT-KNOTHOLE (70).

The UPSHOT-KNOTHOLE Series had two major objectives:

- Improve the nuclear weapons used for strategic bomber delivery and those used for tactical battlefield situations
- Establish military doctrine for the tactical use of nuclear weapons.

To attain these objectives, AEC had planned to conduct scientific experiments during Operation UPSHOT-KNOTHOLE to:

- Prove the adequacy of nuclear devices as warheads before they entered the country's nuclear weapons stockpile
- Test model nuclear devices for development as practical stockpile weapons
- Explore phenomena that could affect the efficiency and performance of nuclear weapons but could not be analyzed theoretically
- Determine the validity of recommendations to improve the efficiency of nuclear weapons
- Observe detonations and obtain new information pertinent to weapons development
- Accelerate the development cycle by substituting tests for lengthy laboratory programs
- Obtain basic scientific information.

Combined AEC and DOD planning continued throughout the summer. By 1 September 1952, AEC plans indicated that the Los Alamos Scientific Laboratory (LASL) would test at least five nuclear devices and that the newly formed University of California Radiation Laboratory (UCRL) at Livermore, California, would test two devices. DOD plans included a military effects test, ENCORE, and an artillery shot, GRABLE. The preliminary test schedule circulated in September underwent several changes as LASL, UCRL, and DOD planning progressed. By early October, DOD had formalized plans for GRABLE, which was to test a nuclear artillery shell fired from a 280mm cannon. DOD then negotiated with AEC to include GRABLE toward the end of Operation UPSHOT-KNOTHOLE (70).

From October to December 1952, DOD and AEC made further changes in the schedule of shots and the nature of test group participation in the events. By mid-December 1952, the UPSHOT-KNOTHOLE tests were scheduled so that:

- No detonation occurred on Sunday.
- Tower shots were one week apart.
- The interval between a tower shot and an airdrop was at least four days.
- Shots ENCORE and GRABLE were at least two weeks apart.

The Test Manager decided not to schedule detonations on Sundays because of numerous complaints concerning previous Sunday tests. The one-week interval between tower shots was based on the time required by Edgerton, Germeshausen, and Grier, Inc. (EG&G) work crews to change test locations and also to provide a one-day rest period each week for test personnel. The Military Effects Group requested the two-week interval between ENCORE and GRABLE to allow time for the group to evaluate damage from ENCORE and reactivate certain stations before the detonation of GRABLE over the same target area (70). Although the test schedule for Operation UPSHOT-KNOTHOLE was revised several times, the testing was on schedule for most nuclear events of the series. Schedule changes in the later part of the series resulted primarily from adverse weather conditions.

Table 1-1 summarizes information about the 11 events in the UPSHOT-KNOTHOLE Series. UTM coordinates* are used to identify the location of the ground zeros (70; 81; 98; 103).

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*Universal Transverse Mercator (UTM) coordinates are used in this report, as seen in table 1-1. The first three digits refer to a point on an east-west axis, and the second three digits refer to a point on a north-south axis. The point so designated is the southwest corner of an area 100 meters square.

Table 1-1. SUMMARY OF OPERATION UPSHOT-KNOTHOLE EVENTS (1953)

Shot	ANNIE	NANCY	RUTH	DIXIE	RAY	BADGER	SIMON	ENCORE	HARRY	GRABLE	CLIMAX
Sponsor	LASL	LASL	UCRL	LASL	UCRL	LASL	LASL	DOD-LASL	LASL	DOD-LASL	LASL
Planned Date	17 March	24 March	31 March	6 April	18 April	11 April	25 April	7 May	2 May	21 May	31 May
Actual Date	17 March	24 March	31 March	6 April	11 April	18 April	25 April	8 May	19 May	25 May	4 June
Local Time*	0520	0510	0500	0730	0445	0435	0430	0830	0505	0830	0415
NPG Location	Area 3	Area 4	Area 7	Area 7	Area 4	Area 2	Area 1	Area 5	Area 3	Area 5	Area 7
UTM Coordinates	871004	797056	868042	871045	806060	784104	798009	956726	867996	956728	872048
Type	Tower	Tower	Tower	Airdrop	Tower	Tower	Tower	Airdrop	Tower	280 mm Cannon	Airdrop
Height of Burst (Feet)†	300	300	300	6,020	100	300	300	2,423	300	524	1,334
Yield (Kilotons)	16	24	0.2	11	0.2	23	43	27	32	15	61

*Pacific Standard Time for Shots ANNIE through SIMON; Pacific Daylight Time for Shots ENCORE through CLIMAX.

†Altitudes are measured from mean sea level, while heights are measured from the ground.
All vertical distances are given in feet.

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1.3 THE NEVADA PROVING GROUND

Operation UPSHOT-KNOTHOLE, like Operations RANGER, BUSTER-JANGLE, and TUMBLER-SNAPPER, was conducted at the Nevada Proving Ground. Originally established in December 1950, the NPG is located in southern Nevada, 100 kilometers* northwest of Las Vegas, as shown in figure 1-1.

The original NPG, shown in figure 1-2, is an area of high desert and mountain terrain of about 1,600 square kilometers in Nye County. On its eastern, northern, and western boundaries, the NPG adjoins the Las Vegas Bombing and Gunnery Range,+ of which it was originally a part. The NPG has been the location for all atmospheric nuclear weapons tests conducted within the continental United States from 1951 to the present.

The nuclear weapons tests of Operation UPSHOT-KNOTHOLE were conducted in two distinct geographical areas: Yucca Flat and Frenchman Flat. Yucca Flat, a desert valley surrounded by mountains, is about 320 square kilometers. Located in the north-central part of the NPG, Yucca Flat was the site of nine UPSHOT-KNOTHOLE tests. The area boundaries outlined in figure 1-2 approximate the Yucca Flat testing area. Frenchman Flat, a dry lake basin encompassing 22 square kilometers, is located in the southeastern part of NPG. Only the two UPSHOT-KNOTHOLE military effects events, Shots ENCORE and GRABLE, were conducted in this area. Yucca Flat and Frenchman Flat are linked by Mercury Highway, which extends north and south through Yucca Pass. Yucca Pass is the site of News Nob, a major observation area, and the Control Point. The Control Point consisted of nine permanent buildings situated on the west side of Yucca Pass. All

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*Throughout this report, surface distances are given in metric units. The metric conversion factors include: 1 meter = 3.28 feet; 1 meter = 1.09 yards; and 1 kilometer = 0.62 miles.

+Now the Nellis Air Force Range

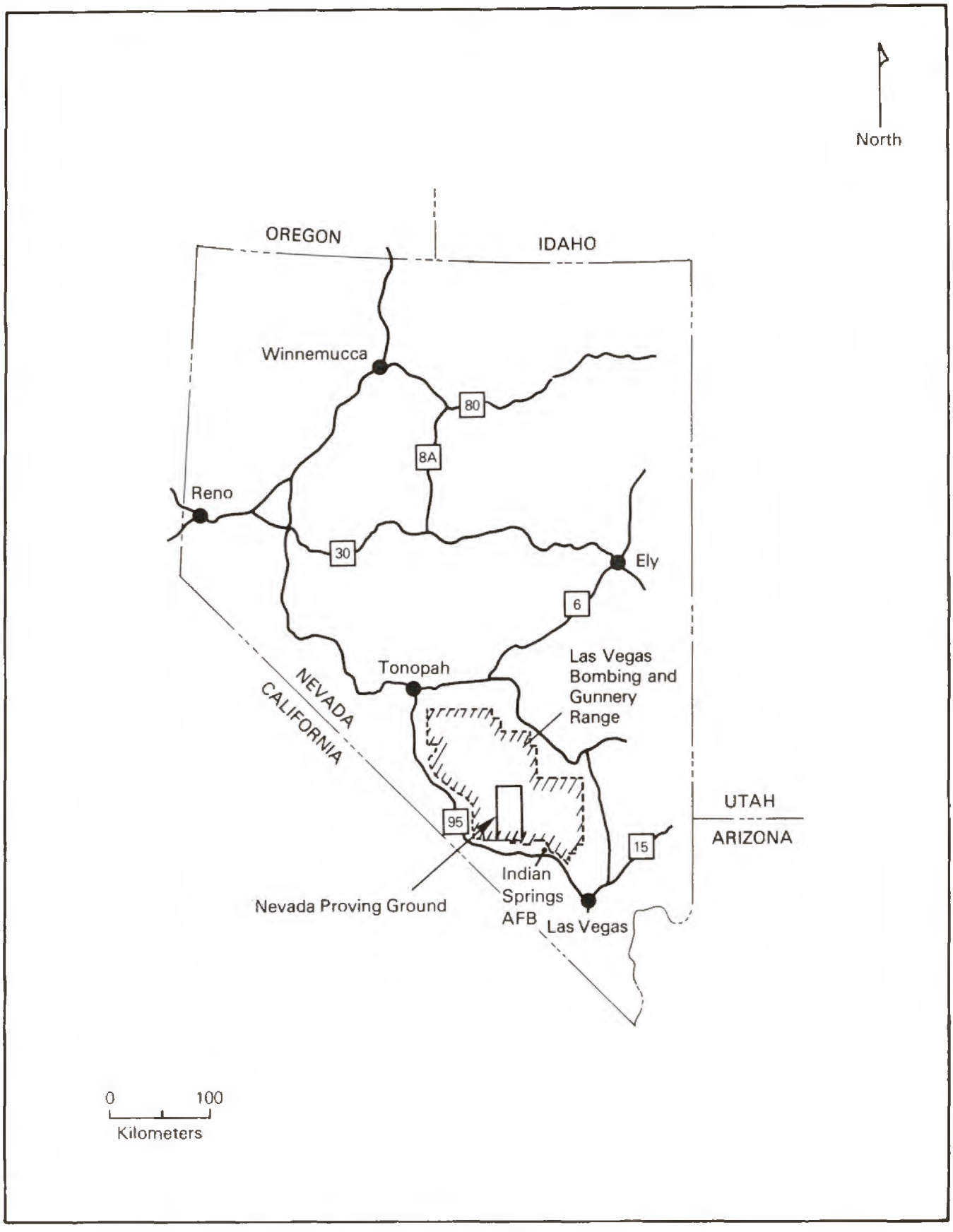

Figure 1-1: LOCATION OF NEVADA PROVING GROUND

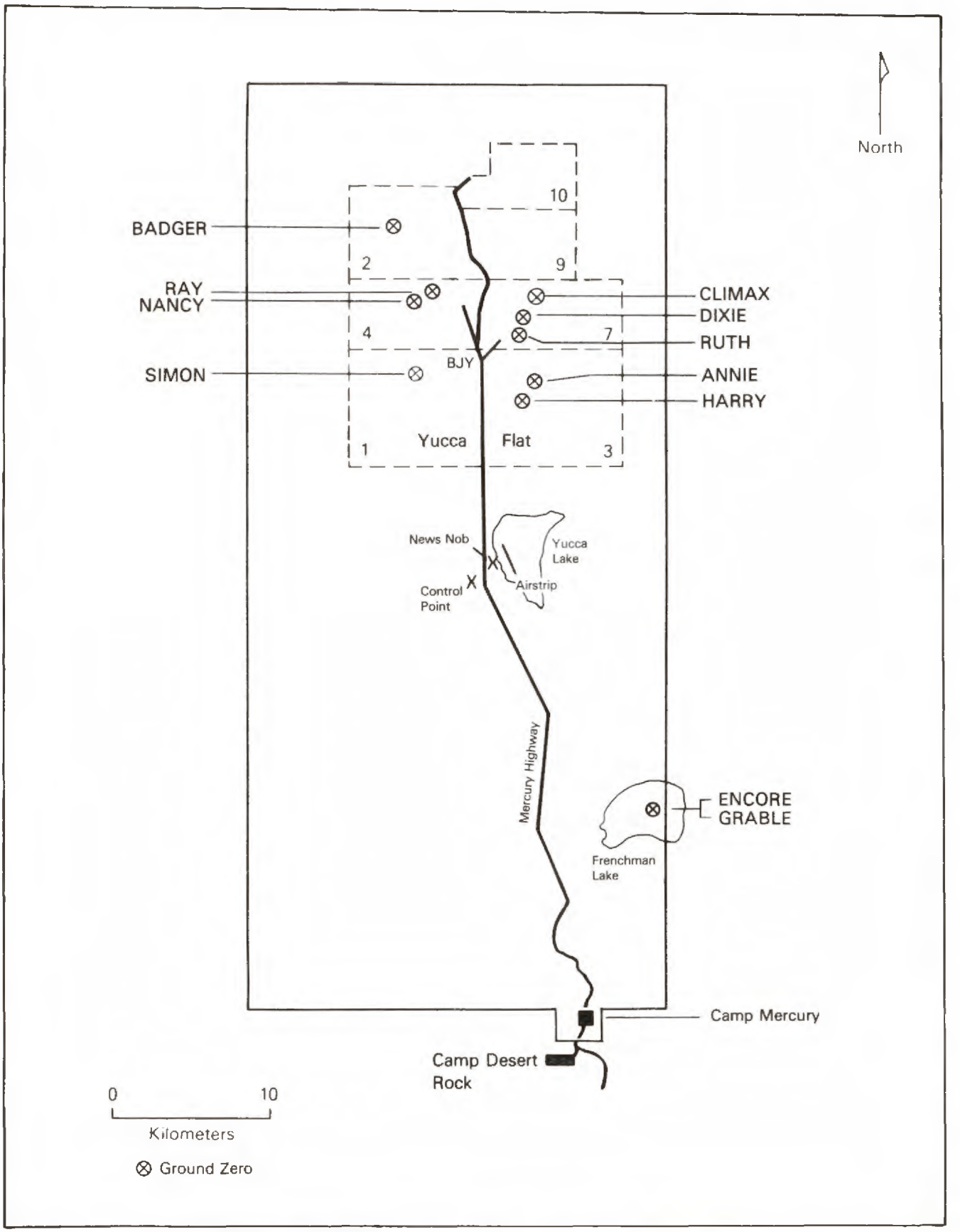

Figure 1-2: NEVADA PROVING GROUND SHOWING GROUND ZEROS FOR OPERATION UPSHOT-KNOTHOLE

tower shots were detonated from Building 1 at the Control Point, since the location permitted visual observation into the forward areas of both Frenchman Flat to the southeast and Yucca Flat to the north. The Control Point was also the location of decontamination facilities for personnel and vehicles returning from some of the testing areas (70; 103).

Camp Mercury, situated at the southern boundary of the NPG, was the base of the Joint Test Organization (JTO), which managed the UPSHOT-KNOTHOLE operations. Camp Mercury provided office and living quarters, as well as laboratory facilities and warehouses, for the personnel participating in the AEC test activities (70).

Camp Desert Rock, headquarters of the Desert Rock exercises, was located just beyond the NPG, three kilometers southwest of Camp Mercury. Camp Desert Rock consisted of Quonset huts and semi-permanent structures supplemented by trailers and tents as necessary. The camp population varied considerably, depending on the schedule of weapons tests and associated troop maneuvers. When tests were not being conducted, fewer than 100 personnel maintained the camp. During test periods, however, Camp Desert Rock often housed several thousand DOD personnel on temporary assignment to participate in the nuclear weapons tests (120-121).

1.4 SUMMARY OF OPERATION UPSHOT-KNOTHOLE EVENTS

During the planning for Operation UPSHOT-KNOTHOLE, AEC directed LASL and DOD to delineate experimental requirements that could be addressed during the 1953 test series. These proposals, when analyzed and evaluated, resulted in the scheduling of the events listed in table 1-1.

The 11 nuclear tests of Operation UPSHOT-KNOTHOLE ranged in yield from less than one kiloton (Shots RUTH and RAY) to the 61-kiloton Shot CLIMAX. Shot GRABLE, the tenth detonation of the

series, was unique not only to Operation UPSHOT-KNOTHOLE but to the entire continental weapons testing series. It was the first test of a nuclear artillery projectile fired from a 280mm cannon. Three of the shots, DIXIE, ENCORE, and CLIMAX, were airdrops. All other devices tested in the UPSHOT-KNOTHOLE Series were detonated on towers, which ranged in height from 100 feet to 300 feet (103). Shots ANNIE, NANCY, BADGER, SIMON, ENCORE, and GRABLE involved the largest number of DOD participants.

1.5 DEPARTMENT OF DEFENSE PARTICIPANTS AND ACTIVITIES

About 21,000 DOD participants, both military and civilian, from the armed services and the Armed Forces Special Weapons Project participated at Operation UPSHOT-KNOTHOLE. By early 1982, the military services had identified 11,277 of these individuals by name.

DOD personnel participated in the following activities:

- JTO administration and support
- Test group scientific and diagnostic activities, including AFSWP military effects projects
- Exercise Desert Rock V support
- Exercise Desert Rock V troop maneuvers and observation projects
- Air Force Special Weapons Center (AFSWC) support.

Approximately 18,000 of the 21,000 participants at Operation UPSHOT-KNOTHOLE took part in Exercise Desert Rock V. The remaining DOD participants at Operation UPSHOT-KNOTHOLE took part in support activities associated with Exercise Desert Rock or in activities of the JTO, the principal authority for planning and directing the series. JTO activities included assisting in the administration of UPSHOT-KNOTHOLE, participating in the scientific and diagnostic programs conducted by the three test groups, or performing AFSWC support missions.

CHAPTER 2

RESPONSIBILITIES OF THE ADMINISTRATIVE ORGANIZATIONS DURING OPERATION UPSHOT-KNOTHOLE

Two groups, the Joint Test Organization and Exercise Desert Rock V, were responsible for the activities conducted during Operation UPSHOT-KNOTHOLE. This chapter describes how both these groups were organized to plan, manage, and conduct the 11 weapons tests and the scientific and military projects that constituted Operation UPSHOT-KNOTHOLE.

JTO included representatives from both the Atomic Energy Commission and the Department of Defense. The primary responsibilities of JTO were to schedule and detonate the nuclear devices being tested and to evaluate the results of each detonation. The Test Manager and his staff performed the first function, while the Scientific Test Director and his staff were responsible for the second. JTO was principally staffed and administered by two Federal agencies, AEC and DOD, with representatives from the Federal Civil Defense Administration (FCDA) and the U.S. Public Health Service (70; 88).

Exercise Desert Rock V was staffed and administered by the Army but included personnel from the other armed services. Exercise Desert Rock V functioned separately from JTO, with liaison established between the two groups to ensure that Desert Rock technical and training programs did not interfere with the JTO scientific and diagnostic programs. Exercise Desert Rock V participants served either as support troops or as exercise troops. Throughout Operation UPSHOT-KNOTHOLE, support troops resided at Camp Desert Rock, located just south of the Nevada Proving Ground. These troops provided security and law enforcement, radiological safety, medical care, transportation, construction, food, and laundry services to the exercise troops.

Exercise troops were assigned to Camp Desert Rock for periods of a few days to a few weeks to participate in a particular program (120-121).

Other participants at UPSHOT-KNOTHOLE included employees of other Federal agencies, research laboratories, and private firms under contract to the Government. DOD personnel participated in the activities of many of these organizations as well (70).

2.1 THE JOINT TEST ORGANIZATION

AEC and DOD shared responsibility for planning and implementing the atmospheric nuclear weapons test program. AEC was responsible for exploring and developing new areas of nuclear weapons technology, while DOD was to incorporate the weapons into the country's military defense program (70).

Congress established the AEC in 1946 with the passage of the Atomic Energy Act. The Director of the AEC Division of Military Application, who was by law a member of the military, supervised nuclear test operations from AEC Headquarters in Washington, D.C. Before Operation UPSHOT-KNOTHOLE, this individual authorized the Manager of the AEC Santa Fe Operations Office to be the Test Manager, delegating to him onsite responsibility for test preparations at the NPG. This responsibility included supervising the preparation and use of the various test areas at the NPG and managing the necessary AEC contractor support for each agency involved in test activities. These tasks were coordinated with the various divisions of the AEC Santa Fe Operations Office, as well as with AEC Field Managers, nuclear weapons development laboratories, AFSWP, FCDA, and other Government agencies. Figure 2-1 shows the lines of authority from the President through both AEC and DOD to JTO (70; 88).

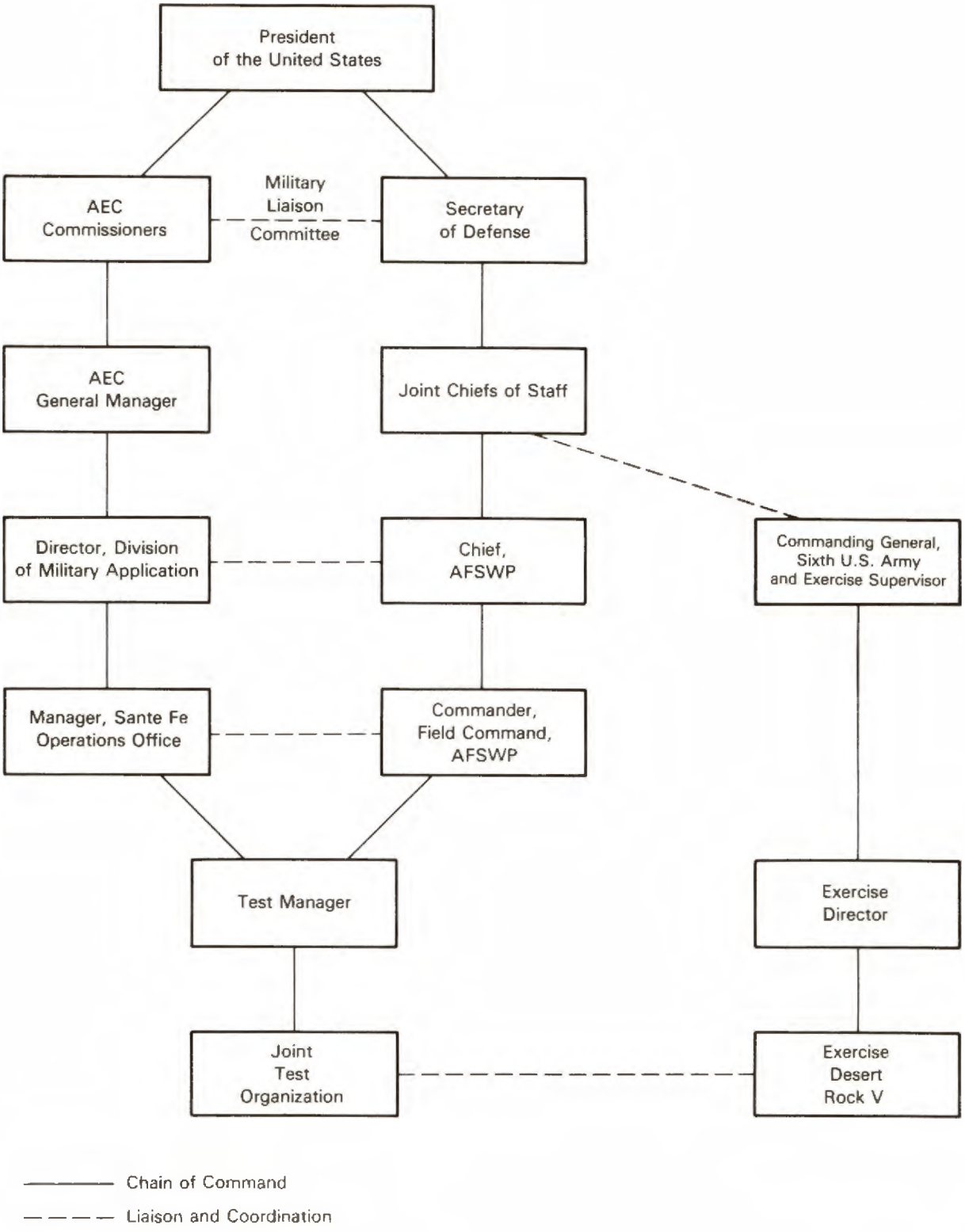

Figure 2-1: JOINT TEST ORGANIZATION/EXERCISE DESERT ROCK V STRUCTURE WITHIN FEDERAL GOVERNMENT

The principal DOD agency responsible for developing nuclear weaponry was AFSWP, which was created by Congress in 1947. The Commander, Field Command, AFSWP, assisted in coordinating and organizing DOD participation by appointing a Deputy for Military Operations to serve on the Test Manager's staff. The Deputy for Military Operations coordinated the various DOD activities at the NPG, including the military effects programs conducted by AFSWP Field Command Military Effects Group in addition to the training programs, troop maneuvers, and technical tests that constituted Exercise Desert Rock V (70; 88).

At the request of the Commander, Field Command, AFSWP, the Commander of AFSWC, at Kirtland Air Force Base (AFB), accepted responsibility for operational control and flight planning of all aircraft participating at Operation UPSHOT-KNOTHOLE. This included all air activities of the Air Force, Army, Navy, Marine Corps, Civil Air Patrol, and civilian aircraft at the NPG. At the request of the Test Manager and the Test Director, the Commander of AFSWC also provided the airdrop aircraft, the sampling aircraft, the cloud tracking, terrain survey, courier, security sweep and shuttle aircraft, and supporting elements. AFSWC provided ground support and air base services at both Kirtland AFB, New Mexico, and Indian Springs AFB, Nevada (94).

As shown in figure 2-1, liaison between AEC and DOD existed at several points. The Atomic Energy Act provided for a Military Liaison Committee consisting of representatives from DOD to consult with AEC on "the development, manufacture, use, and storage of bombs, the allocation of fissionable material for military research, and the control of information relating to the manufacture or utilization of atomic weapons." This committee served as the liaison between the AEC commissioners and the Secretary of Defense (70; 88; 233-234).

The relationship of AEC with DOD was formalized in a memorandum of agreement between the Santa Fe Operations Office and AFSWP Field Command. The memorandum, dated 16 February 1953, stated that in matters relating to DOD participation at the NPG, the Test Manager was responsible to the Commander of AFSWP Field Command. In matters not relating to DOD participation, however, the Test Manager reported to his superior at AEC headquarters, the Director of Military Application. This agreement was confirmed in a letter from the AEC to the Assistant to the Secretary of Defense for Atomic Energy (224).

During the planning and implementation phases of Operation UPSHOT-KNOTHOLE, the Joint Chiefs of Staff coordinated the activities of Exercise Desert Rock V through liaison with the Commanding General of the Sixth U.S. Army, who served as the Exercise Supervisor. At the operational level, the AFSWP representative to the JTO, the Deputy for Military Operations, coordinated Exercise Desert Rock V activities with those of JTO (70; 88; 120-121).

Personnel to staff the various elements of JTO were drawn from the AEC Santa Fe Operations Office, AEC contractors, various DOD agencies, FCDA, and other Federal agencies (70). Approximately 2,000 DOD personnel took part in JTO administration and activities at Operation UPSHOT-KNOTHOLE.

2.1.1 Test Manager's Organization

The Test Manager was responsible for the overall direction of the UPSHOT-KNOTHOLE Series. This responsibility included deciding whether or not to proceed with a shot as planned, coordinating the agencies involved in the weapons development and weapons effects projects, and supervising the units that performed support functions for the test participants (70; 88).

Figure 2-2 shows the Test Manager's organization. The Advisory Panel consisted of representatives from AFSWP Field Command, the U.S. Public Health Service, the U.S. Weather Bureau, and the two AEC nuclear weapons development laboratories, LASL and UCRL. This panel briefed the Test Manager on weather conditions and their potential effect on each scheduled test (44; 70; 88).

The Deputy for Scientific Operations directed all scientific projects conducted by the test groups during Operation UPSHOT-KNOTHOLE. This individual also served as the Test Director. To fulfill this responsibility, the Test Director had his own staff and duties, as described in the next section (70; 88).

The Deputy for Support Operations provided all auxiliary logistical services required for the nuclear tests. He was also the Support Director and, like the Test Director, supervised his own staff (70; 88).

The Deputy for Military Operations was the Test Manager's chief military advisor for military effects testing. This deputy coordinated projects conducted by the Military Effects Group with projects fielded by the Weapons Development Group and the Civil Effects Group. In addition, he served as liaison between the Test Manager and the Deputy Exercise Director for Desert Rock activities. The Deputy for Military Operations was assisted by the Liaison Officer for Troop Participation, who was responsible for ensuring that Desert Rock activities did not interfere with test group projects (70; 88).

The Information Advisory Committee supplied information on test activities to the Test Manager. The Test Information Office, on the other hand, prepared news releases on the nuclear tests for the general public. The Long Range Monitoring Office

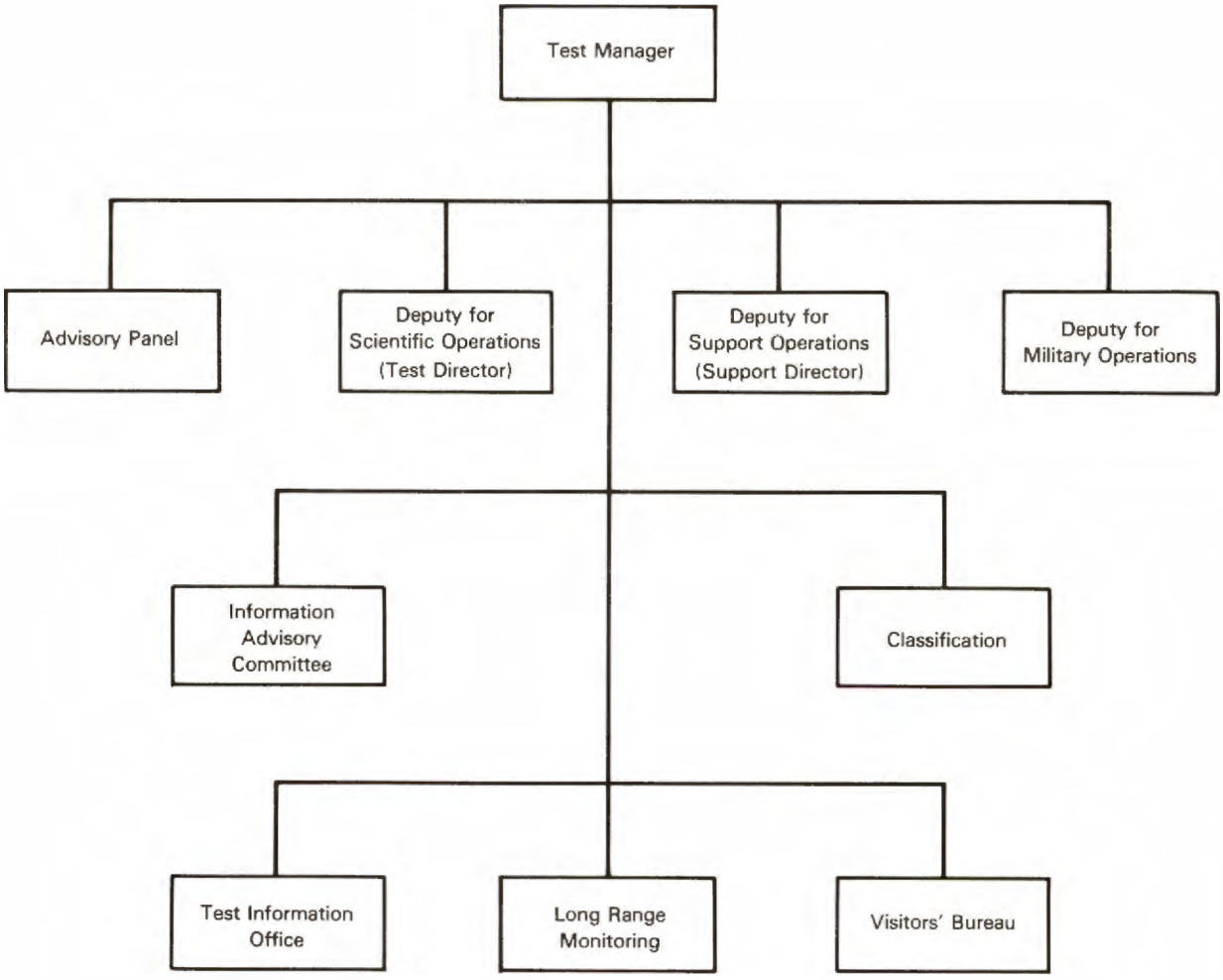

Figure 2-2: TEST MANAGER'S ORGANIZATION

coordinated and recorded offsite radiation fallout information relayed to the JTO by the AEC New York Operations Office. The Classification Office processed security clearances for all JTO personnel at the NPG. The Visitors' Bureau conducted observer programs for AEC, DOD, and FCDA (70; 88).

2.1.2 Test Director's Organization

To ensure that the many scientific and military experiments were conducted safely and efficiently, the Test Manager's Deputy for Scientific Operations provided overall direction to the activities of the test groups that conducted the experiments. As Test Director, the Deputy for Scientific Operations coordinated experiments performed by the Military Effects Group, the Weapons Development Group, and the Civil Effects Group (70; 88).

The Military Effects Group conducted nine programs to evaluate the weapons effects characteristics of each UPSHOT-KNOTHOLE nuclear device detonated. The Weapons Development Group, consisting of representatives of LASL and UCRL, conducted diagnostic experiments to evaluate the nuclear devices detonated. The FCDA Civil Effects Group performed projects to assess the effects of nuclear detonations on civilian structures and food products and to test the capability of civil defense organizations to provide effective rescue, recovery, and support operations in a nuclear emergency. Representatives from each of these three test groups acted as technical advisors to the Test Director (70; 88).

As shown in figure 2-3, the Test Director's Organization included two administrative elements, the Staff and Advisory Section and the Support Section. The Staff and Advisory Section was organized into seven subsections, each responsible for developing operating plans for scientific development, military, and civil effects activities. The Support Section assisted test

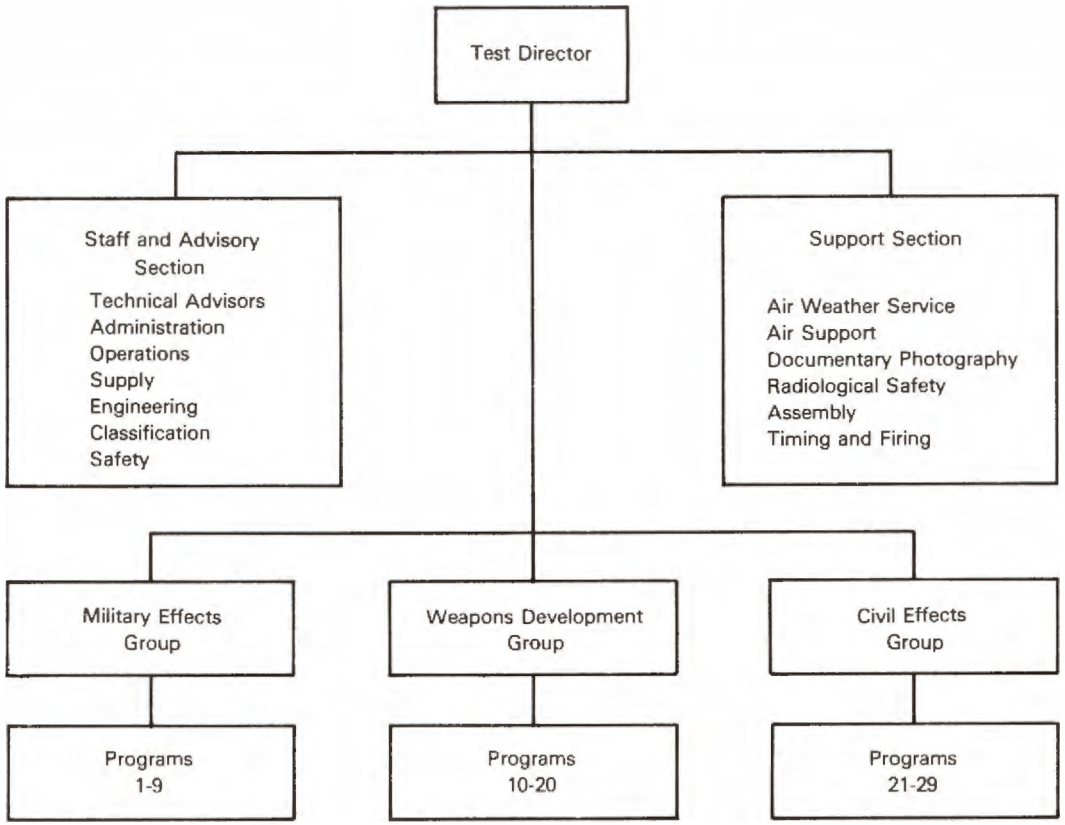

Figure 2-3: TEST DIRECTOR'S ORGANIZATION

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participants on a mission basis. The Support Section personnel providing these services reported directly to the Test Director (70; 88).

A detachment from the 4th Weather Group collected meteorological data from Camp Mercury, the Control Point, and several weather stations surrounding the NPG. About 70 Air Force officers and airmen were involved in Air Weather Service activities during Operation UPSHOT-KNOTHOLE (70).

AFSWC provided air support to AEC, DOD, and other agencies participating in the tests. The Aircraft Participation Unit, staffed by AFSWC and located at the Air Operations Center at the Control Point, exercised operational control over aircraft flying over or near the NPG during and between detonations. AFSWC also provided administrative and logistic support for Aircraft Participation Unit personnel from Indian Springs AFB and Kirtland AFB. AEC provided onsite housing, transportation, and communication and control facilities (70; 94).

The Lookout Mountain Laboratory from Hollywood, California, consisting of the 1352nd Motion Picture Squadron, Air Photographic and Charting Service, provided motion picture and still photography coverage of the scientific and technical programs. It also supplied photographs to the Joint Office of Test Information. The Lookout Mountain Laboratory had ten to 18 participants in Operation UPSHOT-KNOTHOLE (70).

The Radiological Safety Support Unit, ultimately responsible to the Test Director, supervised onsite radiological safety monitors, predicted the onsite radiological environment, and ensured that onsite radiological safety criteria were observed. The Chemical Corps Training Command provided 26 officers and approximately 144 enlisted men from the 9778th Technical Support Unit from Fort McClellan, Alabama. These personnel constituted the core of the Radiological Safety Support Unit. When

necessary, the group was augmented with personnel from other military organizations (70; 74).

The Test Director's technical advisors and support personnel worked together to plan and conduct the day-to-day UPSHOT-KNOTHOLE test activities. The technical advisors reviewed the proposed activities for each program and project of the respective laboratories and agencies. Working with the representatives of the support group and the technical advisors, the Test Director and his staff revised the proposed plans to include scheduling times, locations of necessary construction, supplies, transportation, radiological safety, air support, and postshot recovery operations. The Test Director and his staff presented these revised plans to the Test Manager, who had final authority to review and approve all activities associated with Operation UPSHOT-KNOTHOLE (70).

2.1.3 Support Director's Organization

The Support Director and his staff, shown in figure 2-4, were in charge of all auxiliary services required by the test group programs and Camp Mercury. These services included administration, engineering and construction, communications, transportation, and security. The Support Director's staff was also responsible for offsite radiological safety and the investigation of public damage claims. The Support Director's staff managed the Field Command Support Unit and various contractors (70).

The Field Command Support Unit, the DOD office within the Support Director's organization, performed all base support functions for which DOD was responsible, specifically those involving the Military Effects Group. These functions consisted of procuring supplies necessary for DOD activities coordinated by JTO, transporting DOD personnel, and providing medical and administrative services to DOD personnel (70; 88).

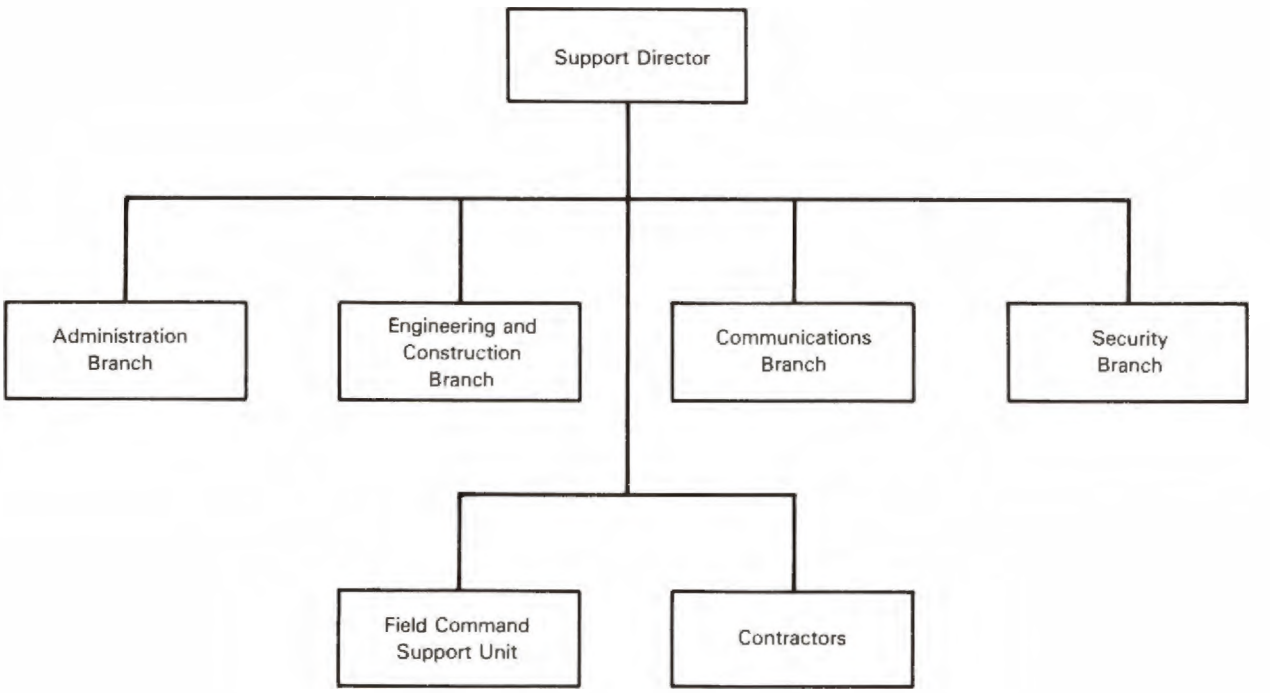

Figure 2-4: SUPPORT DIRECTOR'S ORGANIZATION

AEC contractors provided a number of services to the JTO. The Silas Mason Company provided construction services for some of the Weapons Development Group, Military Effects Group, and Civil Effects Group projects at the NPG. These services included building shot-towers and bunkers to house diagnostic instruments. Other contractors provided miscellaneous equipment and material for construction in the forward areas and maintenance of Camp Mercury. Other AEC contractors included the following (168):

- Food Services, a local company, provided food for AEC personnel
- Reynolds Electrical and Engineering Company (REECo) conducted utility and housekeeping functions at Camp Mercury and provided some construction services for Military Effects Group Projects
- Federal Services, Inc. provided security at Camp Mercury and the NPG (44; 70).

2.2 THE ORGANIZATION OF EXERCISE DESERT ROCK V

Exercise Desert Rock V, which was sponsored by the Department of the Army, involved an estimated 18,000 DOD participants in the orientation activities, tactical troop maneuvers, and training tests conducted at Operation UPSHOT-KNOTHOLE. In addition, about 2,000 DOD personnel were required to administer Camp Desert Rock, support the exercises, and coordinate Desert Rock activities with the activities and programs of the Joint Test Organization (120-121).

Headquarters for Exercise Desert Rock V was formally established in January 1953 when the Commanding General of the Sixth U.S. Army was appointed Exercise Supervisor. The Exercise Supervisor was responsible for overseeing the participation of the armed services and for providing administrative and logistical support to the exercise troops. During the planning phases, the Exercise Supervisor conferred with representatives

of the AEC, Sandia Base, and the AFSWP Field Command office to ensure that Exercise Desert Rock activities were coordinated with those planned for the test groups (146). Throughout both the planning and operational phases of Exercise Desert Rock V, the Exercise Supervisor remained at Sixth U.S. Army Headquarters, located at the Presidio of San Francisco. The Exercise Supervisor designated an Exercise Director who was also Commander of Camp Desert Rock (120-121).

In conducting the exercises and commanding the troops assigned to Camp Desert Rock, the Exercise Director was assisted by the staff shown in figure 2-5. This organization provided the services and supervision necessary to sustain the exercise troops assigned to Camp Desert Rock to participate in specific test activities. The Exercise Director was responsible for supervising the activities of the exercise troops as well as those of the support troops (120-121).

At the administrative level, the Exercise Director's staff was divided into several elements. The Deputy Post Commander for Operations coordinated Desert Rock V activities. Headquarters Commandant provided the Exercise Director with clerical and administrative support and administered the Visitors' Bureau. The Deputy Post Commanders were responsible for specific elements of the Desert Rock staff. The Inspector General reviewed both support and exercise troop activities to ensure compliance with established military procedures. The Public Information Office distributed press releases to national news organizations and to the hometown newspapers of participating troops. The Staff Judge Advocate provided legal services for Camp Desert Rock (120-121).

The G-1, Administration, established personnel management and other administrative policies for Camp Desert Rock and provided such services as records-processing under the Adjutant General, law enforcement under the Provost Marshal, and

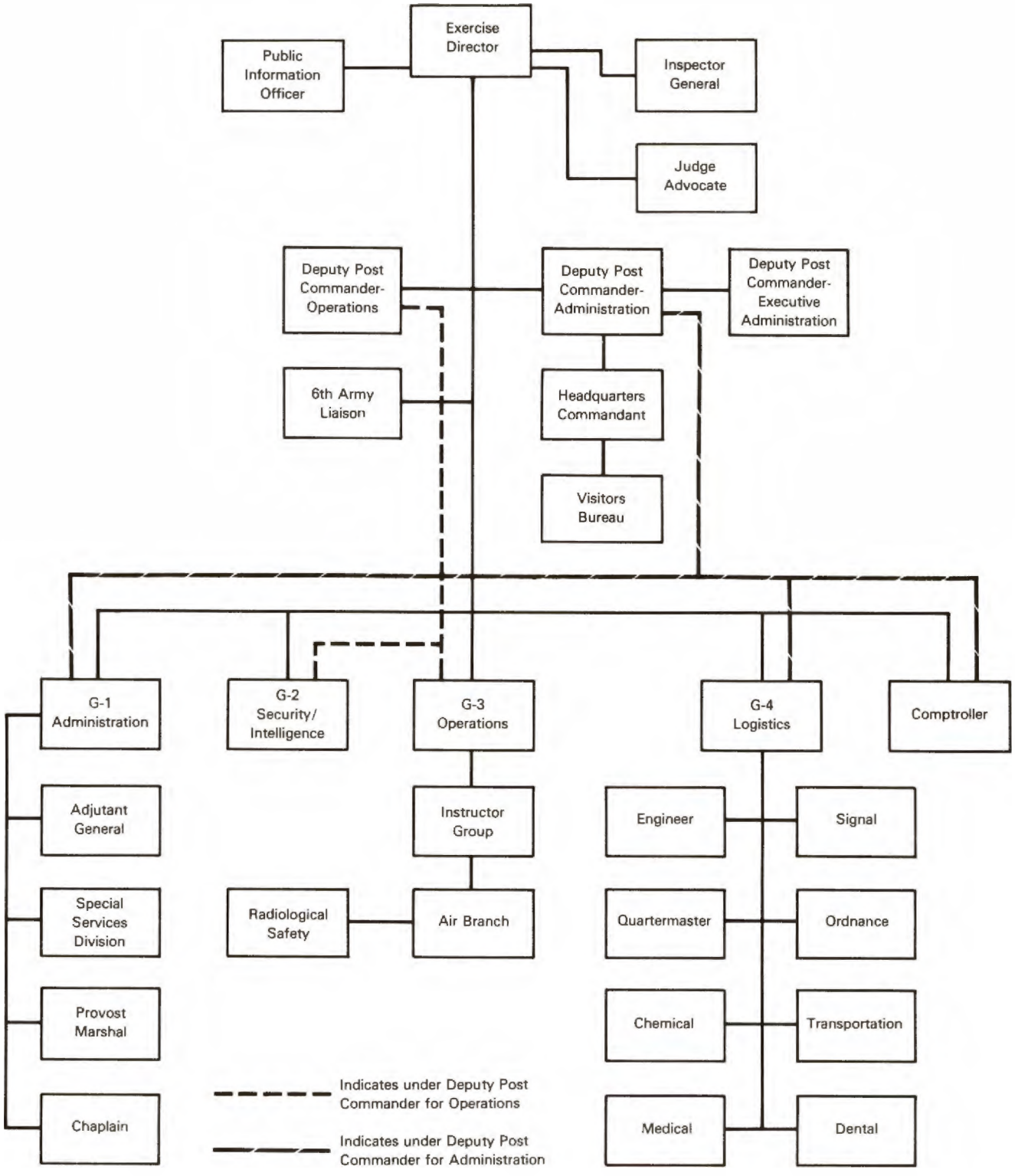

Figure 2-5: CAMP DESERT ROCK ORGANIZATION, EXERCISE DESERT ROCK V, 1953

recreation facilities under Special Services. The Post Exchange and Chaplain were also in the G-1 section. The Provost Marshal was assigned from Headquarters, Sixth Army. Support personnel were provided by Company C, the 505th Military Police Battalion. The Chaplain's Office was served by two reserve officers called to active duty for training (120-121).

The G-2, Security and Intelligence, was responsible for ensuring that proper and adequate security safeguards had been arranged for all classified material connected with Exercise Desert Rock V and that all personnel had proper security clearances. The G-2 maintained close liaison with the Security Branch of the JTO and provided necessary clearance rosters to ensure a smooth flow of troop observer and troop maneuver convoys into the NPG on shot-days (120-121).

The G-3, Operations, was responsible for planning, coordinating, and conducting Camp Desert Rock operations and exercise activities through its three sections (see figure 2-5). The Air Branch, equipped with five fixed-wing aircraft and three helicopters, provided air observation support, air evacuation, courier service, fuel service, and minor aircraft repair. The Air Branch also supplied Army aircraft for radiological safety surveys (120-121).

Members of the Radiological Safety Section planned and conducted the radiological safety procedures used to limit the exposure to exercise troops entering the forward areas. The Desert Rock Radiological Safety Section, which operated separately from the JTO radiological safety organization, had staff supervision of about 70 members of the 50th Chemical Service Platoon. Before each shot, members of the Desert Rock Radiological Safety Section trained exercise troops in radiological safety procedures. After each shot, members of the 50th Chemical Service Platoon accompanied troops into the forward area;

conducted aerial and ground radiological surveys; monitored trenches, equipment displays, and troop maneuver areas; and decontaminated Desert Rock personnel leaving the forward areas. The Desert Rock Radiological Safety Section worked closely with a composite company of the 505th Signal Service Group, which was under the staff supervision of the Signal Officer. This company issued and processed film badges for exercise troops. Chapter 5 of this volume describes in more detail the activities of the 50th Chemical Service Platoon in providing radiological safety services (120-121).

The Instructor Group conducted the orientation program for incoming troops and observers and instructed personnel on the objectives of Exercise Desert Rock V, the capabilities of nuclear weapons, and the protective measures to take against the blast, thermal, and radiation effects of a nuclear detonation. The Instructor Group also performed other tasks, such as controlling troop movement to the forward area, calculating safe distances from the point of detonation for observer activities, and estimating damage to equipment in display areas (120-121).

The 412th Engineer Battalion, supervised by the G-3 Section, constructed trenches and equipment displays in the forward area and participated in projects at Camp Desert Rock when necessary. The battalion also supported the Military Effects Group as necessary (120-121).

The G-4 was responsible for the logistical aspects of Exercise Desert Rock V. The G-4 Section also supervised the activities of the technical services that provided communications, housing, sanitation, transportation, and other support for Camp Desert Rock and Exercise Desert Rock V. Other staff elements organized under the G-4 were as follows (120-121):

- The Signal Section and the 505th Signal Service Group (Composite Company), established wire and radio communications within the test areas and at

Camp Desert Rock. The Signal Section also issued and processed Desert Rock V film badges.

- The Engineer Section and the 360th Engineer Utility Detachment provided supplies, equipment, and personnel for the construction of trenches and test facilities and the maintenance of Camp Desert Rock.

- The Ordnance Section and the 3623rd Ordnance Company procured, distributed, and maintained weapons and vehicles for the exercise troops and equipment display areas.

- The Quartermaster Section, with the 163rd Laundry Company and the 762nd Quartermaster Subsistence Company, provided Desert Rock exercise and support troops with food, clothing, bedding, laundry service, tents, petroleum products, office equipment, and general supplies.

- The Transportation Section was organized into four sections: Camp Transportation Office, Commercial Traffic Section, Supply Section, and the Camp Motor Pool. The Motor Pool was operated by the 26th Transportation Truck Battalion, consisting of the 23rd and 31st Transportation Truck Companies, with driver personnel from the 38th and 53rd Transportation Truck Companies attached.

- The Chemical Section, consisting of personnel from the 50th Chemical Service Platoon, provided equipment and supplies in support of radiological safety operations in the forward areas of the NPG and furnished chemical support to Camp Desert Rock.

- The Medical Section, staffed by personnel from the 94th Veterinary Food Inspection Detachment and the 371st Evacuation Hospital, provided medical aid, men, and ambulances for each observer and troop convoy and established temporary medical aid stations at trench and forward parking areas, and inspected meat brought in for the Camp Desert Rock mess. The Medical Section also provided medical care at Camp Desert Rock for Desert Rock personnel.

- The Dental Section, composed of one dental officer and one dental technician, furnished dental advice and care to Desert Rock personnel.

The support troops described above and organized as shown in figure 2-5 functioned primarily to assist the exercise troops in

performing their tasks. Throughout Exercise Desert Rock V, however, there was a shortage of support troops. At no time during the activities did the actual strength of these troops reach more than 77 percent of the authorized level. Many of the troops had only 30 days or less of military service remaining upon arrival at Camp Desert Rock. This situation created a continual flow of individuals returning to their home stations for release from the service. The constant turnover in personnel resulted in long hours and sometimes seven-day work weeks for the support troops, degraded efficiency of operations, and created a shortage of enlisted specialists, such as mechanics, carpenters, and electricians (121).

CHAPTER 3

EXERCISE DESERT ROCK V PROGRAMS AT OPERATION UPSHOT-KNOTHOLE

Exercise Desert Rock V was designed to train armed services personnel and to study the effects of nuclear weapons. It was a continuation of DOD programs conducted during previous series of atmospheric nuclear weapons tests at the Nevada Proving Ground. Exercises Desert Rock I, II, and III were conducted during Operation BUSTER-JANGLE in late 1951, and Desert Rock IV was conducted during Operation TUMBLER-SNAPPER in 1952. The objectives of the Desert Rock V exercises were to:

- Provide training in the tactical use of nuclear weapons
- Study the effects of a nuclear detonation on animals and equipment
- Determine the effects of a nuclear detonation on field fortifications and defensive structures
- Measure the ability of trained staff officers to estimate target damage
- Observe psychological responses to nuclear detonations
- Provide training in radiological safety measures.

These objectives were similar to those of the preceding Desert Rock exercises (120).

As many as 18,000 of the estimated 21,000 DOD participants at UPSHOT-KNOTHOLE participated in Exercise Desert Rock V. Perhaps another 1,800 personnel were Camp Desert Rock support troops. The remaining DOD personnel took part in JTO activities as described in chapter 4 (120-121).

All Exercise Desert Rock V personnel were assigned to Camp Desert Rock, located just outside the southern boundary of the NPG. Camp Desert Rock support troops were assigned to the camp for up to the entire 12-week period of UPSHOT-KNOTHOLE, while Desert Rock V exercise troops were assigned to camp on a temporary-duty basis.

Camp Desert Rock Troops

The support troops were drawn mainly from units of the Sixth Army. They were generally stationed at the camp throughout the testing series, although many returned to their home bases and were replaced by other troops during the exercise. These soldiers provided necessary support functions for the camp, such as administration, transportation, radiological safety, construction, communications, security, mess, and laundry (121).

Support unit elements frequently entered the forward testing areas of Yucca Flat and Frenchman Flat. There, they helped prepare for specific Desert Rock activities, such as the damage effects evaluation, assisted in operations during test events, or helped ensure safe recovery operations after a shot. Support elements that entered the forward testing area were the Radiological Safety Section, the Instructor Group, and the Control Group. The organization of the Radiological Safety Section is discussed in chapter 2 and its functions in chapter 5 of this volume (120-121).

The Instructor Group prepared and presented orientation programs for observers and maneuver troops. Four Army officers formed the group. In addition, an Army medical officer, a Navy officer, and an Air Force officer, representing the Armed Forces Special Weapons Project, contributed specialized instruction. Before shot-day, the Instructor Group presented basic information on nuclear weapons characteristics and effects, weapons delivery, personal protection, and the medical effects of radiation.

During the rehearsal of shot-day exercises, instructors conducted tours of the equipment and animal display areas for all personnel and predicted the weapon effects. On shot-day, participants arrived at the trenches at least one hour before the detonation. Instructors then began their orientation over the loudspeakers. Following the tactical maneuvers, the instructors led maneuver troops and observers through the display area and discussed the effects of the detonation. The Control Group, consisting of the Headquarters Commandant and selected elements of the G-3 section, including the Instructor Group, supervised troop and observer operations in the forward area. The Control Group accompanied troops into the shot area to ensure that all personnel remained together and followed safety and tactical instructions (120).

Other support elements entering the forward area included the (120):

- 505th Signal Service Group (Composite Company)
- Detachment 371st Evacuation Hospital
- 26th Transportation Truck Battalion (-)*
- Company C, 505th Military Police Battalion
- 412th Engineer Construction Battalion.

The 505th Signal, with approximately 225 personnel, installed radio and wire communications systems, including a public address system, in the main trench areas. On shot-days, two company members operated two mobile public address systems (two trucks with loudspeakers). After receiving clearance from the radiological safety monitors, they moved the system into the display areas, for use by the Instructor Group in its presentations (120-121).

The detachment of the 371st Evacuation Hospital, with a strength of about 30 personnel, provided medical support to Camp

*Some subordinate units were not present.

Desert Rock. Operations orders specified that a detachment consisting of one medical officer and four enlisted men from the hospital would move to the forward area in an ambulance and establish an aid station in a parking area at least eight kilometers from each ground zero. In addition to these medical personnel, the Camp Desert Rock Surgeon accompanied the Control Group to the forward area on shot-day and remained at the forward command post throughout the exercise. Two aidmen accompanied the observer groups. The units that maneuvered as Battalion Combat Teams (BCTs) provided their own medical support (120-121).

The 26th Transportation Truck Battalion (-) consisted of personnel from the 23rd and 31st Transportation Truck Companies, with additional drivers from the 38th and 53rd Transportation Truck Companies. These personnel transported exercise troops from Camp Desert Rock to the forward area. They then moved the vehicles to a parking area located at least eight kilometers from each ground zero. After the detonations and postshot activities, they returned to the loading areas to transport the exercise troops to Camp Desert Rock. The planned strength of the transportation units attached to Camp Desert Rock totaled approximately 252 Army personnel (121).

Company C, 505th Military Police Battalion, whose planned strength was 124 military policemen, controlled the movement of military vehicles in the shot area. Approximately 40 military police participated at the shots that involved large numbers of exercise troops: ANNIE, NANCY, BADGER, SIMON, ENCORE, and GRABLE. Some of the military police were posted at road junctions in the forward area. Others accompanied the units moving from Camp Desert Rock to the trench area. After the exercise troops had been taken to the trench location, the military police went to the parking area. After the detonation, the military police returned to posts at the road junctions to direct traffic from the trench area along the return route to Camp Desert Rock (121).

The 412th Engineer Construction Battalion, whose planned strength was about 660 personnel, prepared trenches and constructed equipment displays in the forward area before the shot. After the shot, they inspected and retrieved display items. Members of the 412th Engineer Construction Battalion were not usually present in the shot area on shot-day. At Shot ANNIE, however, troops from this battalion participated in the troop maneuver, along with other Camp Desert Rock troops (120-121).

Desert Rock V Exercise Troops

Desert Rock V exercise troops consisted of an estimated 18,000 DOD personnel who arrived at Camp Desert Rock to participate in testing and training programs. These exercise troops, unlike the Camp Desert Rock troops, were assigned to Camp Desert Rock to participate in specific activities associated with a particular shot. These activities included (120):

- Troop orientation and indoctrination
- Volunteer officer observer program
- Tactical troop maneuvers
- Operational helicopter tests
- Damage effects evaluation.*

Unlike subsequent nuclear weapons testing series, the activities included in these programs were not called projects and were not identified by a number and name. The number of DOD participants in each program activity at each shot is shown in table 3-1 (70; 111; 115; 120).

The troop orientation and indoctrination program was designed to acquaint official observers and troops from the Army, Navy, Marine Corps, Air Force, and other DOD personnel with the effects of nuclear detonations. The program consisted of

*Personnel for the damage effects evaluation program were drawn from Desert Rock support troops.

Table 3-1: EXERCISE DESERT ROCK V, ESTIMATED NUMBER OF PARTICIPANTS AT OPERATION UPSHOT-KNOTHOLE, BY PROGRAM (68; 109; 113)

Program	Participating Service	ANNIE	NANCY	DIXIE	RAY	BADGER	SIMON	ENCORE	HARRY	GRABLE
Orientation and Indoctrination (Observers)	Army	303	308	0	0	260	198	135	99	606
	Army (Camp Desert Rock)	0	0	60	33	0	0	180	526	0
	Navy	152	86	0	1	122	13	92	14	70
	Marine Corps	9	17	75	25	106	1	12	2	29
	Air Force	41	79	0	4	101	340	113	255	13
Volunteer Officer Observers Program	Army	0	4	0	0	6	7	0	0	0
	Navy	0	4	0	0	0	1	0	0	0
	Marine Corps	0	0	0	0	6	0	0	0	0
	Air Force	0	1	0	0	0	0	0	0	0
Tactical Troop Maneuvers	Army	0	2,349	0	0	0	2,450	2,149	0	2,670
	Army (Camp Desert Rock)	1,181	0	0	0	0	0	0	0	0
	Marine Corps	0	0	0	0	2,167	0	0	0	0
	Air Force	0	0	0	0	0	0	326	0	0
	Navy	0	0	0	0	0	0	0	0	0
Operational Helicopter Tests	Marine Corps	10	9	11	8	11	8	12	10	0
Damage Effects Evaluation	Army	*	*	0	0	*	*	*	*	*

*Unknown

NOTE: Desert Rock V activities were not conducted at Shot RUTH or Shot CLIMAX.

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lectures, films, preshot and postshot tours of equipment display areas, and observation of nuclear detonations in the forward areas of the NPG. During Operation UPSHOT-KNOTHOLE, approximately 4,480 DOD personnel, including 805 Camp Desert Rock support troops, took part in the Exercise Desert Rock orientation and indoctrination program. Some of these personnel participated in more than one shot (120-121).

The volunteer officer observer program was performed for the first time in the history of continental nuclear weapons testing at Exercise Desert Rock V. This program was designed to measure the ability of trained staff officers to calculate safe distances from nuclear detonations and to allow them to experience a nuclear detonation from the distance calculated. The volunteer officer observer program was conducted at Shots NANCY, BADGER, and SIMON (120).

The tactical troop maneuvers were designed to train participants in the use of nuclear weapons and to demonstrate to participants the effects of nuclear detonations. Approximately 13,000 exercise troops and Camp Desert Rock support troops took part in the tactical maneuvers conducted at Shots ANNIE, NANCY, BADGER, SIMON, ENCORE, and GRABLE (120).

The operational helicopter tests were performed by the Marine Corps. This program was designed to investigate the capability of helicopters and their crews to withstand a nuclear burst and the resulting flash, blast, thermal radiation, dust, and contamination. Approximately 40 personnel took part in this program, which was performed at all UPSHOT-KNOTHOLE events except RUTH, GRABLE, and CLIMAX (115; 120).

Damage effects evaluation was performed by officers of various Desert Rock V units to assess the damage to military equipment and vehicles placed in the vicinity of the nuclear

detonations. The program helped the armed services determine how close equipment and vehicles could be positioned to a nuclear detonation and remain in working condition. The same officers were generally involved at each detonation. Their exact number is undetermined (120).

3.1 TROOP ORIENTATION AND INDOCTRINATION AT EXERCISE DESERT ROCK V

Army, Navy, Marine Corps, and Air Force observers participated in troop orientation and indoctrination at Operation UPSHOT-KNOTHOLE. The purpose was to familiarize members of the armed services with the effects characteristic of nuclear detonations. Participants witnessed a nuclear event in the forward area of the NPG and, before and after the detonation, toured a display of ordnance materiel and other military equipment arrayed in the vicinity of ground zero.

The number of Desert Rock observers at each of the test events is depicted by shot and participating service in table 3-1. As the table illustrates, troop orientation and indoctrination were conducted at nine of the 11 tests. The orientation and indoctrination activities involved both Camp Desert Rock observers and other service observers.

Camp Desert Rock observers were not associated with any particular observer activity but were for the most part assigned to Camp Desert Rock support units. They were sent to the forward area to see a shot, possibly in conjunction with a support activity. The size of this group of observers at any nuclear event varied with the participation of other observer and troop maneuver activities. Some Camp Desert Rock support troops may have taken part as observers at more than one nuclear test (120; 122-128).

Service observers were selected from military bases throughout the United States. These personnel participated solely as observers and received the routine preshot briefings and orientation course presented by the Camp Desert Rock Instructor Group. In some instances, participants from this group observed more than one nuclear test (120; 135).

Each service was informed of the reporting and departure date for each shot, as well as the records and equipment to be carried to Camp Desert Rock by individual observers. After arriving at Camp Desert Rock, the observers began a scheduled routine which varied from shot to shot but included a standard set of activities. These activities included preshot classroom instruction in basic nuclear theory, the characteristics and effects of nuclear weapons, protective measures to use against a nuclear attack, and a plan of operations for the upcoming shot. The preshot lectures lasted eight hours. For those observers unable to arrive at Camp Desert Rock in time for this instruction, a one-hour orientation was conducted on the evening before the shot (120; 135).

A rehearsal of shot-day activities was conducted in addition to the preshot classroom instruction. This rehearsal involved a visit to the trenches that the observers would occupy on shot-day, a practice of the countdown and activities scheduled for the detonation, and a tour through the display area. In some instances, the observers toured the display area of a previous nuclear test to see the postshot effects (120).

About one hour before the scheduled shot, observers arrived at the trench area by truck or bus convoy. There they were told what to expect and were briefed on safety procedures. They then entered the trenches, where they crouched for the final countdown and the shot. Figure 3-1 shows troops in trenches awaiting the ANNIE detonation. After some of the shots, they inspected the

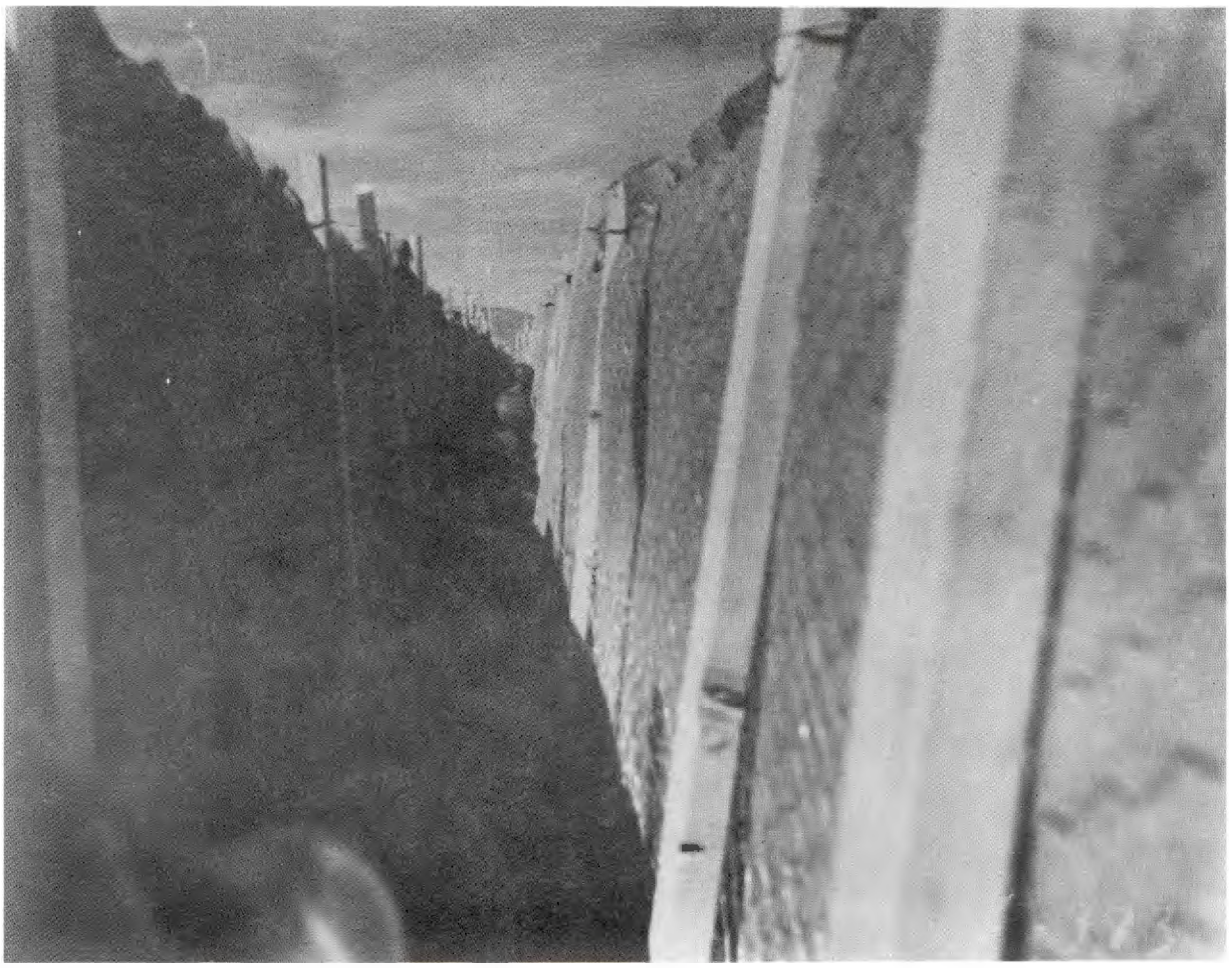

Figure 3-1: TROOPS IN TRENCHES AWAITING THE ANNIE DETONATION

equipment display area to examine the effects of the burst on animals, equipment, and fortifications and shelters. The Desert Rock Control Group supervised this inspection. The service observers and Camp Desert Rock observers probably were located in the same trenches and viewed the equipment display areas together (120; 122-128).

Various circumstances altered this general routine at some of the shots. In some cases, weather conditions or fallout contamination prevented observers from viewing the display area. In other cases, shot delays resulted in changes to some observer activities (120).

3.2 VOLUNTEER OFFICER OBSERVERS AT EXERCISE DESERT ROCK V

In addition to the regular observers who witnessed the UPSHOT-KNOTHOLE tests, 26 officers participated as volunteer officer observers. One Army officer participated in all three events. The program was designed to measure the ability of trained staff officers to estimate and calculate minimum safe distances for observing nuclear detonations. An additional objective was to train participants in protective measures against the effects of a nuclear blast. At UPSHOT-KNOTHOLE, the program was conducted at Shots NANCY, BADGER, and SIMON. At Shot NANCY, four Army, four Navy, and one Air Force officer volunteers were positioned in trenches 2,290 meters from the NANCY ground zero. At Shot BADGER, six Army and six Marine Corps officers occupied trenches 1,830 meters from the BADGER ground zero. At Shot SIMON, seven Army officers and one Navy officer were located in two trenches 1,830 meters from ground zero. The Exercise Director authorized these officer volunteers to position themselves closer to the NANCY, BADGER, and SIMON ground zeros than the distance established for all other exercise troops and to receive a single dose of gamma radiation not to exceed 10.0 roentgens. The officers chose their distance from ground zero by

calculating the effects of the nuclear detonation according to data in a 1952 technical manual, Capabilities of Atomic Weapons (82). Figure 3-2 indicates the types of computations made by the officer observers in determining the position from which they would view the detonation. Figure 3-3 shows the form signed by each volunteer before the detonation. The activities of these volunteer observers are detailed in the UPSHOT-KNOTHOLE single-shot and multi-shot volumes (120-121; 150).

3.3 TACTICAL TROOP MANEUVERS AT EXERCISE DESERT ROCK V

The tactical troop maneuvers at Exercise Desert Rock V were designed to train participants in the effects of tactical nuclear weapons that might be used on a battlefield and to teach participants about the effects of nuclear weapons on animals, equipment, fortifications, and shelters. An important aspect of the program was to determine whether standard ground tactical movements could be employed under the radiological conditions resulting from the use of nuclear weapons. Tactical troop maneuvers were performed at six UPSHOT-KNOTHOLE events: Shots ANNIE, NANCY, BADGER, SIMON, ENCORE, and GRABLE (120).

Units from the six continental Armies and the Navy, Marine Corps, and Air Force traveled to the NPG specifically to participate in the maneuvers. Table 3-2 gives the planned number of participants and the total number of planned and actual participants in the maneuvers at each shot (120).

The military services developed troop maneuvers according to the following scenario. An aggressor with overwhelming forces had invaded the western United States, pushing friendly forces into retreat. The aggressor then established a hypothetical line of strong defensive positions which resisted breakthrough by friendly forces. To gain the offensive and penetrate enemy lines, friendly forces planned a counterattack with nuclear

HEADQUARTERS
CAMP DESERT ROCK
Las Vegas, Nevada

April 1953

SUBJECT: Computations of Volunteered Observers

TO: Commanding General, Camp Desert Rock

1. For the purposes of calculations for troop safety, a maximum expected yield of ___ KT is used for Shot Desert Rock V No. ____. Infinite visibility is assumed. Volunteer observers will be in an open trench ___ feet deep. Observers will wear normal field attire with gas masks. All occupations are based on data from TM 23-200, Capabilities of Atomic Weapons.

2. Established criteria for various effects are shown in the following subparagraphs. Distances from Ground Zero where these respective effects will be experienced have been computed and tabulated.

a. Initial Gamma (5 r) _____ yds

b. Total radiation Dosage (10 r) _____ yds

c. Air Blast (8 psi on the surface) _____ yds

d. Thermal Effects (1 cal/cm^2) _____ yds

3. Recommendations. (Considering 2 above and any other pertinent data).

4. Comments or computations on Ground Shock, Cratering, Base Surge, or any other considerations at the recommended distance.

Figure 3-2: COMPUTATION FORM USED BY VOLUNTEER OBSERVERS (119)

C E R T I F I C A T E

I hereby certify that I have personally and individually computed the effects expected in an open trench located as far forward as _____ yards from Ground Zero of Atomic Detonation Desert Rock V No. ___ .

The validity of these computations is attested to by virtue of my having attended _____

_____.

I volunteer to participate in this exercise by positioning myself in the above mentioned trench.

Figure 3-3: CERTIFICATE OF AGREEMENT USED BY VOLUNTEER OBSERVERS (119)

Table 3-2: PLANNED PERSONNEL ALLOCATIONS AND TOTAL ACTUAL PARTICIPANTS FOR MANEUVERS AT EXERCISE DESERT ROCK V

Participating Service	ANNIE	NANCY	BADGER	SIMON	ENCORE	GRABLE	Total
First Army	0	0	0	0	600	200	800
Second Army	0	800	0	800	0	400	2,000
Third Army	0	600	0	0	1,000	400	2,000
Fourth Army	0	0	0	600	400	600	1,600
Fifth Army	0	400	0	600	0	600	1,600
Sixth Army	0	600	0	400	0	200	1,200
Camp Desert Rock Army Support Troops	1,000	0	0	0	0	0	1,000
Marine Corps	0	0	2,100	0	0	0	2,100
Total Planned Participants	1,000	2,400	2,100	2,400	2,000	2,400	
Total Actual Participants	1,181	2,349	2,167	2,450	2,475 *	2,670	

* Includes 326 Air Force personnel.

weapons. A series of nuclear strikes would be directed behind enemy lines in preparation for an attack. The actual nuclear test detonation was to represent one of the strikes; the maneuvering troops represented one element of the attacking friendly forces (120; 208).

In association with the troop maneuvers at UPSHOT-KNOTHOLE, the Human Resources Research Office (HumRRO) studied the psychological reactions of troops participating in the maneuvers. As a civilian agency under contract to the Department of the Army, HumRRO had also conducted this study at Exercises Desert Rock I, II, and III during the 1951 BUSTER-JANGLE Series and at Desert Rock IV during the 1952 TUMBLER-SNAPPER Series. During UPSHOT-KNOTHOLE, the HumRRO tests were conducted at the events attended by provisional BCTs composed of Army personnel: Shots ANNIE, NANCY, SIMON, ENCORE, and GRABLE. At Shots NANCY, SIMON, and GRABLE, they probably administered a questionnaire, since the size of the BCTs presented a suitable study population. At Shots NANCY, BADGER, and SIMON, HumRRO probably also examined the reactions of officer volunteers. During these six events, HumRRO was particularly interested in (120; 236):

- Observing troop behavior in the trench area immediately before and after the detonation
- Measuring the changes in troop attitudes about nuclear weapons before and after participation in the indoctrination and the maneuvers.

For the series as a whole, the agency assessed factors governing the amount of information on nuclear testing that participants returning to their bases communicated to home station troops. The HumRRO data were to be used by the Army to predict the performance of troops involved in nuclear warfare (120; 236).

At Camp Desert Rock, troop maneuver personnel were organized into composite Battalion Combat Teams. Two BCTs participated at

Shots ANNIE, NANCY, SIMON, ENCORE, and GRABLE. Their activities involved three phases:

- Observing the nuclear blast
- Conducting the tactical maneuver
- Touring the display area.

Several hours before the shot, the BCTs entered the forward area by truck or bus convoy, often with participants in the troop orientation and indoctrination program. The BCTs and the observers then occupied trenches, from which they witnessed the detonation. During Desert Rock V, the troops occupied trenches as close as 3,200 meters from ground zero. They conducted maneuvers closer to ground zero, as allowed by safety guidelines. Some troops operated within 460 meters of ground zero after a blast when radiological conditions met the safety standards (120; 122-128).

After the shot, the BCTs filed out of the trenches and attacked an objective in accordance with the exercise plans. These troops were accompanied by radiological safety monitors and were preceded by radiological survey teams who determined the limits of safe advance. After reaching their objective, or approaching as close as radiation safety standards would permit, the maneuver troops went to the display area (120; 122-128).

The final stage of the troop maneuvers involved a guided tour through the display area. Under the direction of the Desert Rock Control Group, the BCTs joined the observers and inspected the equipment and animal display area. They listened to explanations of the blast damage presented by the Desert Rock Instructor Group. The BCTs and observer groups were then picked up by trucks in the main trench loading zone and returned to Camp Desert Rock (120; 122-128).

3.4 OPERATIONAL HELICOPTER TESTS AT EXERCISE DESERT ROCK V

The Helicopter Atomic Test Unit, 2d Marine Corps Provisional Atomic Exercise Brigade (2d MCPAEB), conducted the operational helicopter tests at UPSHOT-KNOTHOLE. The tests were designed to investigate factors that would determine the extent to which a helicopter and crew could be used to launch a tactical assault on a predetermined objective following a nuclear detonation. Operational helicopter tests were conducted at all events in Operation UPSHOT-KNOTHOLE except Shots RUTH, GRABLE, and CLIMAX (115; 120).

The helicopter tests generally involved the following activities, although there was some variation from shot to shot. Before a shot, three or four H-19 helicopters left the Camp Desert Rock airstrip for the forward area. These helicopters positioned themselves for the nuclear blast in a variety of ways. Some were on the ground, parked from 12 to 18 kilometers from ground zero. Some were hovering in the Yucca Lake area, and some were flying at heights of 400 feet at distances ranging from 8.5 to 20 kilometers from ground zero (115; 120).

After the passage of the blast wave, some of the helicopters flew toward ground zero. Near ground zero, one helicopter performed a radiological survey of the area, while a second hovered nearby in case of emergency. At other shots, two helicopters landed at an area near ground zero to measure and plot the radiation intensities. The helicopters usually returned to Yucca Lake Airstrip, where they were monitored for radiological contamination. After they were cleared, the helicopters returned to Camp Desert Rock (115; 120).

3.5 DAMAGE EFFECTS EVALUATION AT EXERCISE DESERT ROCK V

The damage effects evaluation program enabled military personnel to study the effects of nuclear detonations on animals,

equipment, and field fortifications. Teams of officers from the Camp Desert Rock Chemical, Engineer, Medical, Ordnance, Quartermaster, and Signal Sections inspected the preshot condition of the display area. The teams then witnessed the shot from the observer trenches. After the shot, the teams returned to the display area to compare their predictions with the actual effects of the detonation. The teams participated in all shots except RUTH, DIXIE, RAY, and CLIMAX. The same individuals probably repeated this task throughout the test series (120-121).

CHAPTER 4

DEPARTMENT OF DEFENSE PARTICIPATION IN JOINT TEST ORGANIZATION PROGRAMS AT OPERATION UPSHOT-KNOTHOLE

During Operation UPSHOT-KNOTHOLE, the Joint Test Organization coordinated separate programs of scientific research, including diagnostic studies of the nuclear devices, military effects tests, and tests of the hypothetical effects of nuclear detonations on civilian populations. Air support services, also coordinated by the JTO, were provided to these programs as needed. In most cases, the individual projects conducted under each program required relatively few personnel. Of the DOD personnel participating in UPSHOT-KNOTHOLE, about 1,200 were part of the JTO. Although their numbers were relatively small compared to the 18,000 Desert Rock participants, the JTO participants' activities were significant, since they often repeated their tasks throughout the test series. In contrast, the Desert Rock V exercise troops usually participated in only one or two nuclear tests.

This chapter describes these JTO activities, beginning with the experiments conducted by three test groups (70; 88; 98):

- Armed Forces Special Weapons Project Field Command Military Effects Group
- Los Alamos Scientific Laboratory and University of California Radiation Laboratory Weapons Development Group
- Federal Civil Defense Administration Civil Effects Group.

Composed of scientists and technicians from various military and civilian laboratories, contractors, and the armed services, the test groups developed and conducted field experiments to gather data before, during, and after nuclear detonations.

The Military Effects Group was from Field Command, AFSWP, at Sandia Base, Albuquerque, New Mexico. The mission of the Military Effects Group was to measure weapons effects characteristics and evaluate the military applicability of the nuclear devices designed by the AEC Weapons Development Group. The data obtained were used to improve the nuclear arsenal and expand the techniques and strategies for using that arsenal. At Operation UPSHOT-KNOTHOLE, the Military Effects Group sponsored nine programs subdivided into 81 projects (70; 88; 98).

The Weapons Development Group performed diagnostic tests on the phenomena produced by nuclear devices developed by the AEC weapons development laboratories. The data from these experiments were used to improve nuclear devices, to develop new types of devices, and to test weapons before they entered the nuclear stockpile. The Weapons Development Group sponsored eight programs, consisting of 36 projects, at UPSHOT-KNOTHOLE (70; 88; 98).

The third test group was the FCDA Civil Effects Group. The Civil Effects Group conducted projects for the first time at the Nevada Proving Ground during UPSHOT-KNOTHOLE. This group performed experiments to assess the effects of nuclear detonations on civilian structures and food products. At Operation UPSHOT-KNOTHOLE, the Civil Effects Group conducted eight programs, consisting of 36 projects (70; 88; 98).

Throughout the UPSHOT-KNOTHOLE Series, numbers were used to identify the test group sponsoring the technical programs and experiments (70; 88; 98):

- Programs 1 through 9, Military Effects Group
- Programs 10 through 20, Weapons Development Group
- Programs 21 through 29, Civil Effects Group.

The final section of this chapter describes the air support and services provided by the Air Force Special Weapons Center.

Based at Kirtland AFB, AFSWC supported the Test Manager and the test groups by supplying crews and aircraft for airdrop delivery missions, cloud-sampling and cloud-tracking missions, aerial surveys, and other air missions as requested. The AFSWC Aircraft Participation Unit operated the Air Operations Center, located at the AEC Control Point in Yucca Pass, and maintained operational control over all military aircraft flying over and near the NPG during the entire testing period (94).

4.1 MILITARY EFFECTS GROUP PROGRAMS

The data from the Military Effects Group tests were used to provide a better understanding of the militarily useful effects of nuclear weapons for both offensive and defensive deployment (88). Specifically, the objectives of the Military Effects Group projects were to (88; 98):

- Test the vehicles for delivering the nuclear devices
- Design military equipment able to withstand the effects of a nuclear detonation
- Develop doctrine that incorporated use of nuclear weapons
- Determine the military requirements for future nuclear weapons designs.

The Military Effects Group experiments were divided into three categories (88; 98):

- Basic measurements of the output characteristics of nuclear devices, such as blast, thermal, and radiation measurements
- Tests to determine blast, thermal, and radiation effects on living organisms, structures, equipment, and material

- Operational tests to develop and evaluate techniques and equipment unique to nuclear warfare, such as Indirect Bomb Damage Assessment.

Various military and civilian DOD laboratories and contractors fielded the Military Effects Group experiments. Often, one agency conducting a number of projects with similar objectives used the same instruments and the same project personnel. Likewise, several agencies conducting similar projects sometimes combined equipment and personnel, or compared the data of one agency's project with that of another project. Three projects under Program 3 were specifically designed to provide gauges, recording equipment, and personnel to place the instruments and recover and evaluate data for other Program 3 projects during Shots ENCORE and GRABLE. This type of collaboration reduced the number of experiments in the test areas and limited the number of project participants required to be in the radiation areas. Table 4-1 lists the programs and projects conducted at each shot. Table 4-2 provides a complete list of Program 3 projects conducted during ENCORE and GRABLE, which are too numerous to include in table 4-1 (70; 88; 98).

Two types of documents were used to compile these two tables:

- The weapons test reports, which were prepared after UPSHOT-KNOTHOLE to describe the operations and test results of each project
- The Military Effects Group operational reports, which were compiled from one to three days after each detonation.

These sources are after-action reports and describe actual rather than planned shot participation. Although several other documents are available listing project participation by shot, they indicate planned shot participation only. The tables show the projects actually conducted at each shot (70).

Table 4-1: MILITARY EFFECTS GROUP PROJECT PARTICIPATION BY SHOT

Program Title \ Shot Names	ANNIE	NANCY	RUTH	DIXIE	RAY	BADGER	SIMON	ENCORE	HARRY	GRABLE	CLIMAX
Program 1, Blast and Shock Measurements	1.1a/ 1.2 1.1c-1 1.4		 1.1b	1.1a/ 1.2 1.1b 1.3			 1.1c-1 1.1c-2	1.1a/ 1.2 1.1a-1 1.1a-2 1.1b 1.1d 1.3 1.4	 1.1a-2	1.1a/ 1.2 1.1a-1 1.1a-2 1.1b 1.1d 1.4	1.1a/ 1.2 1.1b 1.1d
Program 2, Nuclear Measurements and Effects		2.2a	2.2a	2.1		2.2a 2.2b	2.2a 2.2b	2.1 2.2a 2.2b 2.3	2.2a 2.2b 2.3	2.2a 2.2b 2.3	2.2a
Program 3, Structures, Material, and Equipment							3.30	*	3.30	*	3.30
Program 4, Biomedical Effects	 4.5	 4.5		4.1		 4.5	 4.5 4.7	4.1 4.2	 4.2 4.5 4.7	 4.2 4.7 4.8	 4.5 4.7
Program 5, Aircraft Structures Test	5.1	5.1		5.2		5.1	5.1	5.1 5.2 5.3	5.1		
Program 6, Test of Service Equipment and Operations	6.2 6.3 6.7 6.8 6.8a 6.9 6.10 6.12	6.2 6.3 6.7 6.8 6.8a 6.9 6.10 6.12	6.2 6.7 6.8a 6.9 6.12	6.2 6.3 6.7 6.8 6.11 6.12	6.2 6.7 6.8a 6.12	6.2 6.3 6.7 6.8 6.8a 6.9 6.10 6.12	6.2 6.3 6.4 6.7 6.8 6.8a 6.9 6.10 6.12 6.13	6.2 6.3 6.7 6.8 6.8a 6.10 6.11 6.12 6.13	6.2 6.3 6.4 6.7 6.8 6.8a 6.10 6.12 6.13	6.2 6.3 6.7 6.8a 6.10 6.12 6.13	6.2 6.3 6.7 6.12
Program 7, Long-range Detection	7.1 7.3 7.4 7.5	7.1 7.3 7.4 7.5	7.1 7.3 7.4 7.5	7.1 7.3 7.4 7.5	7.1 7.3 7.4 7.5	7.1 7.3 7.4 7.5	7.1 7.3 7.4 7.5	7.1 7.3 7.4 7.5	7.1 7.3 7.4 7.5	7.1 7.3 7.4 7.5	7.1 7.3 7.4 7.5
Program 8, Thermal Measurements and Effects	 8.1b 8.2	 8.2 8.5	8.1a 8.1b 8.2 8.10	 8.2 8.10 8.11b	8.1a 8.2	8.1a 8.2	8.1a 8.1b 8.2 8.12a	8.1a 8.1b 8.2 8.4.1 8.5 8.6 8.9 8.10 8.11a 8.11b 8.12a 8.12b 8.13	 8.1b 8.2	 8.1b 8.2 8.4.1 8.4.2 8.5 8.6 8.9 8.10 8.11a 8.11b 8.12a 8.12b	 8.9 8.10
Program 9, Technical Photography	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1 9.6 9.7	9.1	9.1 9.6 9.7	9.1

*See table 4-2 for a complete listing of Program 3 projects conducted at Shots ENCORE and GRABLE.

Table 4-2: MILITARY EFFECTS GROUP PROGRAM 3 PROJECT PARTICIPATION AT SHOTS ENCORE AND GRABLE

Program Title	ENCORE	GRABLE
Program 3, Structures, Material, and Equipment	3.1	3.1
	3.1u	3.1u
	3.3	3.3
	3.4	3.4
	3.5	3.6
	3.7	3.7
	3.8	3.8
	3.9	3.9
	3.11-3.16	3.11-3.16
		3.18
	3.19	3.19
	3.20	3.20
	3.21	3.21
	3.22	3.22
	3.24	3.24
	3.26	3.26
	3.27	
	3.28.1	3.28.1
	3.28.2	3.28.2
	3.28.3	3.28.3
	3.29	
	3.30	3.30

This section details the objectives and general procedures employed for each project. The pertinent shot volumes contain information regarding the number of personnel involved at each shot, their distances from ground zero, and their activities at a particular shot.

4.1.1 Program 1: Blast and Shock Measurements

Program 1, Blast and Shock Measurements, investigated basic blast phenomena. Similar experiments were conducted at previous test series. The experiments were designed to determine optimum height of burst for various yields and related blast parameters useful in assessing and predicting blast damage effects. Nine projects were conducted under Program 1 during Operation UPSHOT-KNOTHOLE. Table 4-3 lists the Program 1 projects at Operation UPSHOT-KNOTHOLE, states the purpose of each project, the shots in which the project was fielded, and the participating groups (70; 98).

Projects 1.1a/1.2, Air Blast Measurements, measured blast pressures at various distances from the nuclear detonation, on the ground, in free air, and on various surfaces, and studied shock wave behavior. Project 1.1a personnel placed pressure gauges on and in the ground and at various heights above the ground along three blast lines radiating from the intended ground zeros for Shots ENCORE and GRABLE. Part of this project also is discussed as Project 1.1a-2. At Shots ANNIE, DIXIE, ENCORE, GRABLE, and CLIMAX, Project 1.2 personnel placed rocket launchers along lines on one side of the burst point and high-speed cameras on the opposite side in order to film smoke rocket trail distortions to determine shock wave behavior. At Shots ENCORE and GRABLE, they also photographed the shock front along the main blast lines. Figure 4-1 shows smoke trails at the detonation of Shot GRABLE (191).

Table 4-3: MILITARY EFFECTS GROUP PROJECTS CONDUCTED AS PART OF PROGRAM 1 DURING OPERATION UPSHOT-KNOTHOLE

Project	Title	Project Objectives	Shots	Participants
1.1a/1.2	Air Blast Measurements	To measure pressure changes at various distances from a nuclear detonation	ANNIE, DIXIE, ENCORE, GRABLE, CLIMAX	Naval Ordnance Laboratory
1.1a-1	Evaluation of Wiancko and Vibrotron Gauges and Development of New Circuitry for Atomic Blast Measurements	To evaluate instruments for measuring blast parameters	ENCORE, GRABLE	Naval Ordnance Laboratory
1.1a-2	Development of Mechanical Pressure-time and Peak Pressure Recorders for Atomic Blast Measurements	To evaluate mechanical blast gauges	ENCORE, HARRY, GRABLE	Naval Ordnance Laboratory
1.1b	Air Pressure and Ground Shock Measurements	To compare blast effects for shots at various heights of burst	RUTH, DIXIE, ENCORE, GRABLE, CLIMAX	Stanford Research Institute
1.1c-1	Air Shock Pressure-time versus Distance for a Tower Shot	To measure pressure changes due to a tower nuclear detonation	ANNIE, SIMON	Sandia Corporation; Ballistic Research Laboratories ; * Naval Ordnance Laboratory*
1.1c-2	Air Shock Pressures as Affected by Hills and Dales	To evaluate the effects of terrain on the blast wave produced by a nuclear detonation	SIMON	Sandia Corporation
1.1d	Dynamic Pressure versus Time and Supporting Air Blast Measurements	To measure the pressure, near the ground, caused by a nuclear detonation	ENCORE, GRABLE, CLIMAX	Sandia Corporation
1.3	Free-air Atomic Blast Pressure Measurements	To measure pressures caused by air bursts at levels below existing data	DIXIE, ENCORE	Air Force Cambridge Research Center
1.4	Free-field Measurements of Earth Stress, Strain, and Ground Motion	To measure blast effects on the earth	ANNIE, ENCORE, GRABLE	Sandia Corporation

*Participated only at SIMON

Figure 4-1: SMOKE TRAILS FOR MEASURING BLAST FORCES, PROJECT 1.1a/1.2 AT SHOT GRABLE

Project 1.1a-1, Evaluation of Wiancko and Vibrotron Gauges and Development of New Circuitry for Atomic Blast Measurements, tested four types of experimental blast gauges and tested the response characteristics of a gauge used in many pressure time studies. Personnel in Project 1.1a assisted in the field. Before Shots ENCORE and GRABLE, personnel placed the instruments along blast lines around ground zero. They recovered the blast gauge data after each detonation (203).

Project 1.1a-2, Development of Mechanical Pressure-time and Peak Pressure Recorders for Atomic Blast Measurements, was designed to evaluate two types of mechanical air-blast gauges. This project utilized the same pressure gauges as a portion of Project 1.1a (199).

Project 1.1b, Air Pressure and Ground Shock Measurements, was conducted to gather data on the blast pressure variations on the ground and just above and below ground surface. Personnel placed blast and pressure gauges and accelerometers at various distances from each intended ground zero, usually along blast lines used by other projects studying blast phenomena. The gauges were calibrated in the field before and after each shot. After detonation, participants retrieved the gauge data (226).

Project 1.1c-1, Air Shock Pressure-time versus Distance for a Tower Shot, was conducted at Shots ANNIE and SIMON. At ANNIE, the objective was to record pressure changes and to use these data to predict changes in pressure at Shot SIMON. At SIMON, measurements were made to compare the predicted with the actual pressures. At Shot ANNIE, the Sandia Corporation and the Ballistic Research Laboratories placed pressure gauges, and at Shot SIMON, the Ballistic Research Laboratories, Sandia Corporation, and the Naval Ordnance Laboratory placed gauges and took measurements. Personnel placed gauges and meters in the

field before each shot. The project required no shot-day recovery operations (211; 221).

Project 1.1c-2, Air Shock Pressures as Affected by Hills and Dales, was performed to define the behavior of the blast wave as it passed over the top of a ridge. Project personnel placed pressure recording instruments in front, behind, and along the ridge before the shot and recovered the data recorded on the instruments after the shot (183; 211).

Project 1.1d, Dynamic Pressure versus Time and Supporting Air Blast Measurements, was fielded to measure blast wave pressures near ground level and to evaluate new and modified pressure, density, temperature, and particle velocity gauges. Project personnel placed pressure gauges along blast lines extending from ground zero. Project 1.1d personnel also placed gauges on bridge structures for Project 3.4 and in the tree stand for Project 3.19 at Shots ENCORE and GRABLE (51; 211).

Project 1.3, Free-air Atomic Blast Pressure Measurements, was fielded to determine the peak overpressure for airburst nuclear devices. The Air Force Cambridge Research Center fielded the project at Shots DIXIE and ENCORE because their points of detonation were high enough above the ground to give a good separation of the direct and ground-reflected blast waves. Shortly before the detonation, two B-29s dropped parachute-borne canisters, which were instrumented to determine pressure at various elevations as they fell. Project personnel near Yucca Lake recorded data transmitted from the canisters (110).

Project 1.4, Free-field Measurements of Earth Stress, Strain, and Ground Motion, had two parts. The objective of the first part was to measure the extent to which various depths of earth cover reduced the vertical forces produced by a nuclear

detonation. The objective of the second part was to test instrumentation used to measure forces transmitted through the earth. Only the first part of Project 1.4 was conducted at Shots ENCORE and GRABLE, while the second part was also performed at ANNIE. Project personnel placed air-pressure gauges, ground accelerometers, and earth stress and strain gauges in the field before each shot (202; 211).

4.1.2 Program 2: Nuclear Measurements and Effects

Program 2, Nuclear Measurements and Effects, studied the radiation produced by a nuclear detonation. This program continued measurements of radiation and its biological effects taken at all previous nuclear weapons test series. Program 2 measured neutron radiation and prompt and residual gamma radiation. As part of the evaluation of the military significance of these phenomena, this program investigated the size, radioactivity, and biological effects of particles within the clouds formed by the detonations. Energy spectrum measurements of the residual radiation were also made to supply information necessary for the design of radiation-measuring equipment. In addition, neutron measurements were made for comparison with measurements at Shot GRABLE, which was expected to have a high neutron flux. The four projects listed in table 4-4 were part of Program 2 at Operation UPSHOT-KNOTHOLE (98).

Project 2.1, Radioactive Particle Studies inside an Aircraft, was developed to determine the concentration of radiation entering a cockpit and evaluate the inhalation hazard to which aircraft personnel would be exposed upon flying through a nuclear cloud. Project personnel placed instrumentation in two drones used for Project 4.1, Radiation Hazards to Personnel within an Atomic Cloud. Project 2.1 was conducted at Shots DIXIE and ENCORE (56).

Table 4-4: MILITARY EFFECTS GROUP PROJECTS CONDUCTED AS PART OF PROGRAM 2 DURING OPERATION UPSHOT-KNOTHOLE

Project	Title	Project Objectives	Shots	Participants
2.1	Radioactive Particle Studies inside an Aircraft	To evaluate internal radiation exposures obtained by flying through a nuclear cloud	DIXIE, ENCORE	Chemical and Radiological Laboratories
2.2a	Gamma Radiation Spectrum of Residual Contamination	To evaluate the biological hazard of residual gamma radiation resulting from tower and air shots	NANCY, RUTH, BADGER, SIMON, ENCORE, HARRY, GRABLE, CLIMAX	Signal Corps Engineering Laboratories
2.2b	Residual Ionizing Radiation Depth Dose Measurements in Unit-density Material	To evaluate the biological hazard of residual beta and gamma radiation	BADGER, SIMON, ENCORE, HARRY, GRABLE	Naval Medical Research Institute
2.3	Neutron Flux Measurements	To evaluate the physical characteristics of the neutron flux produced by a nuclear device	ENCORE, HARRY, GRABLE	Naval Research Laboratory

Project 2.2a, Gamma Radiation Spectrum of Residual Contamination, was fielded to characterize the residual gamma ray contamination resulting from both tower shots and airbursts. The project was conducted at Shots NANCY, RUTH, and BADGER to familiarize personnel with instruments and enable modifications in experimental designs. The project was canceled at Shot DIXIE because of the low level of residual radiation. Data gained from Shots SIMON, ENCORE, HARRY, GRABLE, and CLIMAX were to be used in designing radiation detection devices and in assessing the biological significance of residual gamma contamination. Personnel measured radiation intensities from one hour to ten days after the detonation at positions near ground zero for airbursts and at distances ranging from five to nine kilometers from ground zero for tower shots (4; 45).

Project 2.2b, Residual Ionizing Radiation Depth Dose Measurements in Unit-density Material, was conducted to evaluate the biological effects of residual beta and gamma radiation

fields. Project personnel placed dose-measuring equipment in fallout fields at various locations and times after each shot. The equipment was in spheres and phantoms made of materials that had a density similar to that of the outer layer of human skin (58).

Project 2.3, Neutron Flux Measurements, measured the neutron flux at various ranges from a nuclear detonation. Such measurements had initially been taken at Operation TUMBLER-SNAPPER. GRABLE was of particular interest because high neutron fluxes were anticipated. Personnel placed neutron-detecting material on stakes and cables in the field before each shot and recovered these samples after the detonation (235).

4.1.3 Program 3: Structures, Material, and Equipment

Program 3, Structures, Material, and Equipment, continued from earlier series the study of blast and shock effects of nuclear detonations on vehicles and buildings. Program 3 involved more projects at UPSHOT-KNOTHOLE than did any other program conducted during the series. These projects, listed in table 4-5, included extensive testing of a variety of concrete and steel buildings and vehicles placed near ground zero. The data from these projects were used to assess the potential damage from nuclear detonations to large, fixed targets and rigid structures. Many of the structures tested were prefabricated, shipped to the NPG, and assembled either by contractors or by the 412th Engineer Construction Battalion. Most of the projects required the placing of electronic gauges along blast lines, on structures, and in other areas of predicted overpressure. The gauge responses were recorded, and the recordings were interpreted. Project 3.28, a three-part project, placed instruments and compiled data for other Program 3 projects (98).

Table 4-5: MILITARY EFFECTS GROUP PROJECTS CONDUCTED AS PART OF PROGRAM 3 DURING OPERATION UPSHOT-KNOTHOLE

Project	Title	Project Objectives	Shots	Participants
3.1	Tests on the Loading of Building and Equipment Shapes	To augment existing information on the effects of the blast on various structures, material, and equipment	ENCORE, GRABLE	Air Materiel Command; Armour Research Foundation
3.1u	Shock Diffraction in the Vicinity of a Structure	To determine changes in the shock wave pattern as it diffracted around a structure	ENCORE, GRABLE	Naval Ordnance Laboratory
3.3	Test on the Loading of Horizontal Cylindrical Shapes	To increase the knowledge of blast loadings on structures of cylindrical shape	ENCORE, GRABLE	Air Materiel Command; Armour Research Foundation
3.4	Tests on the Loading of Truss Systems Common to Open-framed Structures	To determine blast forces on open frame structures, such as bridges	ENCORE, GRABLE	Air Materiel Command; Armour Research Foundation
3.5	Tests on the Response of Wall and Roof Panels and the Transmission of Load to Supporting Structure	To determine the load produced by the nuclear blast	ENCORE	Air Materiel Command; Armour Research Foundation
3.6	Tests on the Loading and Response of Railroad Equipment	To study the vulnerability of various types of railroad equipment to the blast and thermal effects produced by a nuclear detonation	GRABLE	Army Transportation Corps; Air Materiel Command; Armour Research Foundation
3.7	Air Blast Effects on Entrances and Air Intakes of Underground Installations	To obtain basic data from which criteria could be developed in designing underground shelters	ENCORE, GRABLE	Office, Chief of Engineers, U.S. Army; Structural Research Laboratory, University of Illinois*
3.8	Air Blast Effects on Underground Structures	To obtain necessary blast data for designing underground protective shelters	ENCORE, GRABLE	Office, Chief of Engineers, U.S. Army; Structural Research Laboratory, University of Illinois
3.9	Field Fortifications	To obtain data on the blast effects and radiation measurements on field fortifications	ENCORE, GRABLE	Engineer Research and Development Laboratories*
3.11-3.16	Navy Structures	To test the protection afforded by various structures against the effects of a nuclear blast	ENCORE, GRABLE	Navy Bureau of Yards and Docks*
3.18	Minefield Clearance	To observe the effects of a nuclear blast on pressure-activated land mines	GRABLE	Engineer Research and Development Laboratories; 412th Engineer Construction Battalion; 44th Infantry Division

* Other participating agencies are listed in the text.

Table 4-5: MILITARY EFFECTS GROUP PROJECTS CONDUCTED AS PART OF PROGRAM 3 DURING OPERATION UPSHOT-KNOTHOLE (Continued)

Project	Title	Project Objectives	Shots	Participants
3.19	Blast Damage to Coniferous Tree Stands by Atomic Explosions	To assess the degree of damage to material and personnel and the amount of cover the forest affords	ENCORE, GRABLE	Forest Service
3.20	Blast and Thermal Effects of an Atomic Bomb on Typical Tactical Communication Systems	To determine the effects of a nuclear blast on signal communication-electronics	ENCORE, GRABLE	Signal Corps Engineering Laboratories; 16th Signal Service Battalion (Corps), Detachment A; 412th Engineer Construction Battalion; Lookout Mountain Laboratory; Coles Signal Laboratory
3.21	Statistical Estimation of Damage to Ordnance Equipment Exposed to Nuclear Blasts	To obtain data on damage to various weapons and vehicles in order to predict what proportion of vehicles would be available for combat within a given time after exposure to a nuclear blast	ENCORE, GRABLE	Ballistic Research Laboratories
3.22	Effects on Engineer Bridging Equipment	To determine the effects of a nuclear blast on pre-fabricated inflexible military bridging	ENCORE, GRABLE	Engineer Research and Development Laboratories
3.24	Effects of an Airburst Atomic Explosion on Landing Vehicles Tracked (LVT)	To determine the degree of blast damage landing vehicles would sustain from a nuclear explosion	ENCORE, GRABLE	Naval Radiological Defense Laboratory
3.26	Test of the Effects on POL Installations	To determine the resistance of equipment and materials of an amphibious assault fuel handling system	ENCORE, GRABLE	Air Materiel Command; Armour Research Foundation; Office of the Quartermaster General; Marine Corps Schools
3.27	Effects of Atomic Explosions on Field Medical Installations Equipment	To determine the effects of a nuclear explosion on field medical installations and equipment	ENCORE	Brooke Army Medical Center
3.28.1	Structures Instrumentation	To provide instrumentation for other Program 3 projects	ENCORE, GRABLE	Ballistic Research Laboratories
3.28.2	Pressure Measurements for Various Projects of Program 3	Same as above	ENCORE, GRABLE	Naval Ordnance Laboratory
3.28.3	Pressure Measurements on Structures	Same as above	ENCORE, GRABLE	Stanford Research Institute
3.29	Blast Effects of Atomic Weapons upon Curtain Walls and Partitions of Masonry and Other Materials	To measure the effectiveness of wall partitions commonly used in conventional framed buildings in resisting blast pressures striking perpendicular to the surfaces	ENCORE	Federal Civil Defense Administration
3.30	Air Blast Gauge Studies	To test a new self-contained recording gauge for the measurements of pressure-time phenomena from a nuclear blast	SIMON, ENCORE, HARRY, GRABLE, CLIMAX	Ballistic Research Laboratories

Project 3.1, Tests on the Loading of Building and Equipment Shapes, was conducted by the Air Materiel Command. The Armour Research Foundation was a primary contractor for this project and for other Program 3 projects conducted by the Air Material Command. The objective was to augment existing information concerning blast effects on simple structures differing in size, shape, and orientation to the detonation.

To conduct this experiment, personnel assembled 15 structures along a circular arc at a distance of about 1,500 meters from the intended ground zero for Shots ENCORE and GRABLE (same intended ground zero). Two additional models were positioned 350 and 670 meters from ground zero. All were constructed of reinforced concrete on firm foundations and were filled with soil. Personnel from the Ballistic Research Laboratories, the Stanford Research Institute, and the Naval Ordnance Laboratory, as part of Project 3.28, mounted about 235 gauges on the test structures (102; 184; 189; 225).

Project 3.1u, Shock Diffraction in the Vicinity of a Structure, was fielded by the Naval Ordnance Laboratory. The objective was to determine changes in the shock wave pattern as it diffracted around a structure. The project used the Project 3.1 structure located 670 meters from the ground zeros of Shots ENCORE and GRABLE. The Naval Ordnance Laboratory, as part of Project 3.28, mounted 14 pressure-time gauges around the structure to measure diffraction of the shock wave (150; 189).

Project 3.3, Tests of the Loading of Horizontal Cylindrical Shapes, was conducted by the Armour Research Foundation, under contract to the Air Materiel Command. The general objective was to increase the knowledge of blast loadings on cylindrical structures. Five steel cylinders with reinforced end-sections were supported above the ground at two stations for both ENCORE and GRABLE. The two stations were located 1,460 and 1,910 meters

from the intended ground zero. For each shot, Ballistic Research Laboratories personnel, as part of Project 3.28, attached 30 air pressure gauges and ten strain gauges to the cylinders (216).

Project 3.4, Tests on the Loading of Truss Systems Common to Open-framed Structures, was conducted by the Air Materiel Command, which contracted the project to the Armour Research Foundation. The project studied the effects of a nuclear blast on open-framed structures, such as bridges. The data obtained were to be compared with wind tunnel data and information gathered during the previous nuclear weapons testing series (215).

Five open-framed structures were used at both ENCORE and GRABLE. The structures duplicated the center sections of open-deck, single-track railroad bridges. Project 3.28 personnel mounted strain gauges on the foundations of the structures. At ENCORE, the structures were arranged approximately 670 to 710 meters from ground zero. The same structures were used at GRABLE (215).

Project 3.5, Tests on the Response of Wall and Roof Panels and the Transmission of Load to Supporting Structures, was conducted by the Armour Research Foundation, under contract to the Air Materiel Command. The objective was to determine the load, as produced by a nuclear blast, transmitted to building frames through various common types of panel wall and roof construction.

Three reinforced concrete structures were fitted with wall panels and roofs constructed of cinder block, brick, corrugated steel, wood, or reinforced concrete. The structures were positioned 2,040, 1,370, and 670 meters from the ENCORE ground zero. The two structures farthest from ground zero were designed and used for Project 3.29. Project 3.28 personnel instrumented each structure with gauges to measure pressure and strain. Motion

picture cameras were set up at the two stations farthest from ground zero to film the movement of the test structures (218).

Project 3.6, Tests of the Loading and Response of Railroad Equipment, was conducted by the Army Transportation Corps and the Air Materiel Command, whose contractor was the Armour Research Foundation. The objective was to study the vulnerability of various types of railroad equipment to the blast and thermal effects of a nuclear detonation. Sixteen items of railroad rolling stock were placed on small track sections in groupings 460 to 2,010 meters from the GRABLE ground zero. Railroad stock included tank cars, boxcars, and a diesel electric locomotive (217).

Project 3.7, Air Blast Effects on Entrances and Air Intakes of Underground Installations, was conducted by the Office, Chief of Engineers, and its contractor, the University of Illinois. The objective was to obtain basic data from which criteria could be developed for designing entrances to underground shelters. The Army was particularly interested in problems associated with the design of closed protected structures that could withstand very high pressures. The structures had to protect against biological, chemical, and radiological warfare agents, as well as against blast effects. The parts of the structures most vulnerable to air blast were air ducts, ventilating equipment, and the doors and entryways of the structure.

Personnel constructed one large shelter for testing at ENCORE and GRABLE, 290 meters from the intended ground zero of the shots. The structure was divided into several small chambers outfitted with different air intake ventilation systems. Naval Ordnance Laboratory personnel mounted 34 pressure gauges on the structure before Shot ENCORE and recalibrated them before Shot GRABLE as part of Project 3.28 (223).

Project 3.8, Air Blast Effects on Underground Structures, was performed by the Office, Chief of Engineers, and its contractor, the University of Illinois. The objective was to obtain data necessary for designing underground protective shelters, particularly the roofs of the shelters. Three reinforced-concrete boxes with roofs of simply supported steel-beam strips were positioned on an arc approximately 280 meters from the intended ground zero for ENCORE and GRABLE. The structures were instrumented with gauges to measure strain, deflection, and earth pressure. Ballistic Research Laboratories personnel mounted air pressure gauges on the floors and walls as part of Project 3.28 (194).

Project 3.9, Field Fortifications, was conducted by the Engineer Research and Development Laboratories with assistance from:

- The 412th Engineer Construction Battalion
- The Naval Ordnance Laboratory
- The Naval Material Laboratory
- The Naval Radiological Defense Laboratory
- The Ballistic Research Laboratories
- The Signal Corps Engineering Laboratories.

The objective was to obtain data on blast effects and to measure nuclear and thermal radiation in field fortifications that included standard command posts, two-man foxholes, and machine gun positions. The fortifications were positioned 150, 460, and 1,220 meters from the ENCORE and GRABLE ground zero. Five two-man foxholes, two at 1,220 meters and three at 2,290 meters from ground zero, were constructed and instrumented with various types of pressure-time gauges. Twenty-two foxholes, located 1,220, 1,830, and 2,440 meters from ground zero, were each lined with aluminum sheeting. Several of the positions were covered or revetted (100).

Projects 3.11-3.16, Navy Structures, were conducted by the Navy Bureau of Yards and Docks with assistance from (161):

- Naval Civil Engineering Research and Evaluation Laboratory
- Stanford Research Institute
- Ballistic Research Laboratories
- Naval Ordnance Laboratory
- Public Building Service
- Army Signal Corps
- AFSWP.

The overall objective was to test the protection afforded by various structures against the effects of a nuclear blast. The six projects each tested a particular structure (161):

- 3.11, steel warehouses
- 3.12, brick buildings and precast panels
- 3.13, precast gable shelters and blast-resistant panel
- 3.14, precast warehouse
- 3.15, steel arch ammunition magazine with earth cover
- 3.16, prefabricated wood paneled structures containing various types of window glass hardware.

Various AEC contractors began onsite construction on 1 January 1953 and completed it by April. The structures at ENCORE and GRABLE were positioned on arcs ranging 820 to 6,100 meters from ground zero. Ballistic Research Laboratories and Naval Ordnance Laboratory personnel interspersed gauges measuring pressure, deflection, strain, torque, and shear among the structures as part of Project 3.28 (161).

Project 3.18, Minefield Clearance, was conducted to study the effects of a nuclear blast on pressure-activated land mines. The Engineer Research and Development Laboratories supervised the project. A company from the 412th Engineer Construction Battalion and personnel from the 44th Infantry Division, Fort Lewis, Washington, performed the extensive fielding operations necessary. They buried 2,000 indicator mines and 1,200 live mines (including antitank and antipersonnel mines) in various patterns in the test area, which was about 820 meters from the intended ground zero of Shot GRABLE (209).

Project 3.19, Blast Damage to Coniferous Tree Stands by Atomic Explosions, was fielded by the Department of Agriculture. Associated with a study originally initiated by the Department of the Army on the effects of a nuclear explosion over a forested area, this project assessed the degree of damage to trees and the amount of cover provided by a forest.

Eight days before the shot, project personnel placed 145 trees, gathered from forest reserves near the NPG, in a grove 50 meters wide by 100 meters long. They positioned additional trees in two lines ranging 1,525 to 2,440 meters from the intended ground zero and at 460 meters. Project 3.28 personnel placed instrumentation along the lines of trees and in the stand of trees (213).

Project 3.20, Blast and Thermal Effects of an Atomic Bomb on Typical Tactical Communications Systems, was fielded by personnel from (91):

- Signal Corps Engineering Laboratories
- Detachment A, 16th Signal Service Battalion (Corps)
- 412th Engineer Construction Battalion
- Coles Signal Laboratory
- Army Corps of Engineers.

The objective was to determine the effects of a nuclear blast on signal-communication electronics. Personnel assembled such material as pole lines, towers, and radios on radial arcs 90 to 4,570 meters from the planned ground zero for Shots ENCORE and GRABLE (91; 120).

Project 3.21, Statistical Estimation of Damage to Ordnance Equipment, was fielded by personnel from the Army Ordnance School, Ballistic Research Laboratories, and Camp Desert Rock ordnance support units. Project 3.28 provided instrumentation. The objective was to obtain data on damage to various weapons and vehicles for predicting the percentage of equipment that would be usable in combat after exposure to a nuclear blast.

Before the shots, participants placed about 95 pieces of equipment, including trucks, artillery pieces, and tanks, in side-on, rear-on, and face-in positions 110 to 2,000 meters from the intended ground zero. They attached gauges to the frames of the equipment to measure the impact of the blast. Project 9.1 personnel also used movie cameras to record the effects of the detonation (53).

Project 3.22, Effects on Engineer Bridging Equipment, was fielded by the Engineer Research and Development Laboratories. The objective was to determine the effects of a nuclear blast on prefabricated bridging. The 412th Engineer Construction Battalion erected bridge spans and sections before Shot ENCORE. Two bridges were tested, each a 30-meter, double-truss, single-story Bailey bridge. One bridge was tested at Shot ENCORE, and two were tested at Shot GRABLE. In addition, single-bay aluminum sections were exposed at 320 to 460 meters from the two ground zeros (188).

Project 3.24, Effects of an Airburst Atomic Explosion on Landing Vehicles Tracked (LVT), was fielded at ENCORE and GRABLE

by Naval Radiological Defense Laboratory and Marine Corps personnel. The objective was to determine the blast effects on amphibious landing vehicles and the degree of protection afforded by the vehicles. Six LVTs were positioned 240 to 1,370 meters from the ENCORE ground zero and 310 to 1,050 meters from the GRABLE ground zero. Still photographs were taken before and after each test. Each vehicle was ringed with dosimeters to measure gamma radiation (201).

Project 3.26, Tests of the Effects on POL* Installations, was conducted in three parts. The Air Materiel Command conducted Project 3.26.1, Test of the Effects on POL Installations. Project 3.26.2, Effects of Atomic Weapons on a POL Supply Point, was conducted by the Quartermaster Research and Development Field Evaluation Agency. Project 3.26.3, Effect of an Atomic Explosion upon an Amphibious Assault Fuel Handling System (Shore Phase), was conducted by the Marine Corps Schools. The overall objective of Project 3.26 was to determine the effects of nuclear detonations on POL installations. Each agency designed the project to test types of storage tanks and storage-handling methods peculiar to its respective service. Test items included standard 55-gallon storage drums filled with diesel fuel or gasoline, vertical storage tanks, and various fuel-related equipment.

Silas Mason constructed the actual installations. Project 3.28 personnel instrumented the tanks and equipment to measure air pressure and temperature. Project 9.1 personnel photographed the results. POL installation storage units and equipment for these three agencies ranged from 70 to 3,100 meters from the ENCORE ground zero and from 230 to 4,570 meters from the GRABLE ground zero (219).

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*Petroleum, oil, and lubricants

Project 3.27, Effects of Atomic Explosions on Field Medical Installations Equipment, was fielded by personnel of the Brooke Army Medical Center and the Army Medical Field Service School. At Shot ENCORE, two types of composite field medical installations were placed both above ground and in dug-in positions to determine the effects of a nuclear blast on field medical installations and equipment and to evaluate the degree of protection afforded by placing such installations partially within dug-in positions.

The first type of installation, consisting of a composite battalion aid station and a regimental collection station, was established at sites 1 and 2, located 1,270 and 2,740 meters from ground zero, respectively. The second type, consisting of a composite division clearing station, mobile Army surgical hospitals, and evacuation hospitals, was positioned at sites 1 and 2 and at site 3, located 4,570 meters from ground zero (60).

Project 3.28 had three parts:

- Project 3.28.1, Structures Instrumentation, conducted by the Ballistic Research Laboratories
- Project 3.28.2, Pressure Measurements for Various Projects of Program 3, conducted by the Naval Ordnance Laboratory
- Project 3.28.3, Pressure Measurements on Structures, conducted by the Stanford Research Institute.

The 3.28 projects were developed during the planning of UPSHOT-KNOTHOLE, when the Army, Navy, and Air Force requested that AFSWP arrange for a contractor to handle the instrumentation of Program 3, Structures, Material, and Equipment. The responsibilities were to include procuring instruments, determining proper instrumentation layout, installing and operating the instruments, and compiling the field data for the sponsoring agencies. AFSWP assigned the Ballistic Research Laboratories to coordinate the overall structures instrumentation program. The

Ballistic Research Laboratories received detailed requirements from the agencies that were planning the projects and developed the three parts of Project 3.28 to accomplish the work. AFSWP assigned military personnel to the Ballistic Research Laboratories and the Naval Ordnance Laboratory for these projects.

Project 3.28.1, Structures Instrumentation, provided instrumentation and data analysis for nine projects at Shot ENCORE and ten projects at Shot GRABLE. Project 3.28.2, Pressure Measurements for Various Projects of Program 9, provided instrumentation support for six Program 3 projects. Project 3.28.3, Pressure Measurements on Structures, supported one project at Shots ENCORE and GRABLE. In addition, Project 3.28.2 provided instrumentation and personnel to take measurements for Project 1.1a, another Naval Ordnance Laboratory project.

Personnel for the three parts of Project 3.28 arrived in February 1953 to begin calibrating and placing gauges along the blast line for ENCORE and GRABLE. All gauges were attached to cables that ran to recording instruments in shelters or vans located near the blast line. The day before each detonation, personnel checked the instrumentation. Three-man teams recovered data tapes as soon as recovery hour was announced. The tapes were reproduced at stations, probably located at Camp Mercury, and a copy was given to the project officers involved. Personnel from the sponsoring agencies then indicated the points of interest on the tapes and returned the tapes to Project 3.28 personnel for final analysis (184; 189; 225).

Project 3.29, Blast Effects of Atomic Weapons upon Curtain Walls and Partitions of Masonry and Other Materials, was fielded by the Federal Civil Defense Administration. The purpose of this test was to measure the resistance of wall partitions commonly used in conventional buildings to blast pressures perpendicular to the surfaces. This project was conducted at Shot ENCORE only.

The two test structures, nicknamed "the motels," were long, low, narrow buildings of reinforced concrete. The front test walls were strung with gauges to measure air pressure and displacement. One structure was located about 2,020 meters from ground zero, and the other about 1,340 meters from ground zero (228).

Project 3.30, Airblast Gauge Studies, was conducted by personnel of the Ballistic Research Laboratories. The objective was to test new self-contained recording gauges for the measurement of pressure-time and peak pressure phenomena from a nuclear blast. The gauges were used in conjunction with other projects as back-up gauges and for comparison with other gauge measurements (156).

4.1.4 Program 4: Biomedical Experiments

Program 4, Biomedical Experiments, consisted of five projects that studied the biological effects of nuclear weapons. This program was designed to define and evaluate the hazards to individuals in the vicinity of a nuclear detonation. The experiments sought to determine the hazards associated with flying through the cloud resulting from a detonation, entering an area contaminated with residual radiation, experiencing a blast wave, and seeing the initial flash of a nuclear detonation. For some projects, experimental equipment was not placed in the field until after the detonation, while for other projects, experimental animals were placed in the field before the detonation and recovered later. Table 4-6 lists the five projects conducted as part of Program 4 during Operation UPSHOT-KNOTHOLE (14; 98).

Project 4.1, Radiation Hazards to Personnel within an Atomic Cloud, tested animals in drone aircraft to evaluate various hazards a flight crew might encounter while flying a modern military aircraft through the cloud resulting from a detonation.

During the flight, the drones collected cloud samples through wing-tip filter chambers to compare radiation intensities outside the aircraft with those in the cockpit. In addition, a B-50 and a B-47, both operated by AFSWC, released instrumented canisters through the cloud. Project participants retrieved the canisters the day after the shot. Project personnel recovered the animals after the drones landed at Yucca Airstrip on shot-day (157).

Table 4-6: MILITARY EFFECTS GROUP PROJECTS CONDUCTED AS PART OF PROGRAM 4 DURING OPERATION UPSHOT-KNOTHOLE

Project	Title	Project Objectives	Shots	Participants
4.1	The Radiation Hazard to Personnel within an Atomic Cloud	To determine the hazards a crew might encounter while flying in a modern military aircraft through a nuclear cloud	DIXIE, ENCORE	Air Force Cambridge Research Center; Air Force School of Aviation Medicine; 3205th Drone Group; 4925th Test Group
4.2	Direct Air Blast Exposure Effects in Animals	To evaluate blast injuries received by rats and dogs within air-raid shelters and underground bunkers	ENCORE, HARRY, GRABLE	Naval Medical Research Institute
4.5	Ocular Effects of Thermal Radiation from Atomic Detonation	To determine the visual effects produced by a nuclear detonation	ANNIE, NANCY, BADGER, SIMON, HARRY, CLIMAX	Air Force School of Aviation Medicine
4.7	Beta-gamma Skin Hazard in the Postshot Contaminated Area	To measure total radiation dose to human skin in an area contaminated by a nuclear detonation	SIMON, HARRY, GRABLE, CLIMAX	Walter Reed Army Medical Center
4.8	The Biological Effects of Neutrons	To measure the biological effects of neutrons on animals in the open and in foxholes	GRABLE	Naval Radiological Defense Laboratory

Project 4.2, Direct Air Blast Exposure Effects in Animals, was to compare blast injuries received by rats and dogs within aluminum cylinders covered with sandbags and dirt. For Shot HARRY, empty cages with pressure gauges were exposed as a preliminary test for the animal experiments at GRABLE. At ENCORE and GRABLE, personnel placed animals in the field and recovered them after the shot. Figure 4-2 shows rat cylinders used for the project (89).

Figure 4-2: RAT CYLINDERS USED IN PROJECT 4.2 AT SHOT ENCORE

Project 4.5, Ocular Effects of Thermal Radiation from Atomic Detonation, determined the degree to which the flash of a nuclear detonation impairs night vision. Individuals in darkened trailers 11 to 22 kilometers from ground zero witnessed the nuclear detonations through experimental filters that protected the eyes from much of the visible and infrared portion of the spectrum. Subjects then performed a number of visual tasks to determine the extent of visual impairment. This part of the project was conducted at five shots. In the second part, rabbits were placed at various distances close to ground zero before six shots to determine the distance at which retinal burns could be produced. After the shot, personnel recovered the rabbits and examined their eyes for any damage (54).

Project 4.7, Beta-gamma Skin Hazard in the Postshot Contaminated Area, compared the effects of beta and gamma radiation exposure on material similar to human skin. For this project, performed at four shots, personnel placed phantoms containing thin-walled and thick-walled ion chambers on wooden racks in areas with radiation measurements of 0.8 roentgens per hour (R/h) after each detonation. Personnel remained in the 0.01 R/h area and returned to retrieve the experiments about 30 minutes after they had placed them (50).

Project 4.8, The Biological Effects of Neutrons, determined effects of neutron radiation on animals in 14 above-ground stations and six foxholes. Before Shot GRABLE, project personnel placed mice at slant distances of 450 to 1,800 meters from the burst point. After the shot, personnel retrieved the animals (57).

4.1.5 Program 5: Aircraft Structures Test

Program 5, Aircraft Structures Test, was designed to continue studies conducted at Operations GREENHOUSE and TUMBLER-SNAPPER on the response of aircraft in flight to the thermal and

blast effects of nuclear detonations. For Program 5, three different types of aircraft were tested: the AD, the B-50, and the B-36. The aircraft were instrumented to measure blast and thermal effects and were flown at various distances from tower and airburst detonations. In addition, Navy AD aircraft and components were exposed at ground locations during Shot ENCORE. The three projects conducted as part of Program 5 are listed in table 4-7 (87-88).

Table 4-7: MILITARY EFFECTS GROUP PROJECTS CONDUCTED AS PART OF PROGRAM 5 DURING OPERATION UPSHOT-KNOTHOLE

Project	Title	Project Objectives	Shots	Participants
5.1	Atomic Weapon Effects on AD Type Aircraft in Flight	To study blast and thermal effects on Navy single-engined bombers in flight	ANNIE, NANCY, BADGER, SIMON, ENCORE, HARRY	Navy Bureau of Aeronautics
5.2	Atomic Weapon Effects on B-50 Type Aircraft in Flight	To determine nuclear weapons effects on a B-50 delivery aircraft	DIXIE, ENCORE	Wright Air Development Center
5.3	Blast Effects on B-36 Type Aircraft in Flight	To measure blast effects on a B-36D delivery aircraft	ENCORE	Wright Air Development Center; Strategic Air Command

Project 5.1, Atomic Weapon Effects on AD Type Aircraft in Flight, was conducted to study the blast and thermal effects of a nuclear detonation on AD aircraft. The first part of the project involved gathering data concerning blast and thermal effects on an aircraft in level-flight attitude with its tail toward the blast. This position represented an escape configuration for an AD aircraft after delivering a nuclear weapon. The AD aircraft was unmanned at Shots NANCY, SIMON, and HARRY, and manned at Shots ANNIE and ENCORE. At Shot BADGER, the AD drone aircraft did not take part in the project because of remote-control failure. However, five aircraft that were to accompany the drone were in the air when it was determined that the drone would not be used. Those aircraft were assigned an orbit position for timing practices during actual shot conditions (94; 165; 210).

The second part of Project 5.1 was designed to supplement information on the effects of thermal radiation. Paint finishes and aluminum alloy panels of various thicknesses were exposed at three ground stations during Shot ENCORE. Project 5.1 personnel were assisted in this activity by the following groups (210):

- Douglas Aircraft Company
- Electronics Association
- Massachusetts Institute of Technology, Department of Aeronautical Engineering
- Naval Air Development Squadron Five
- Naval Material Laboratory
- Naval Ordnance Test Station
- Bureau of Aeronautics.

Project 5.2, Atomic Weapon Effects on B-50 Type Aircraft in Flight, was performed to determine the minimum safe altitude for delivery of nuclear weapons from bomber aircraft. Two B-50s were at Shot DIXIE and three at ENCORE. The crews established flight patterns simulating the position of a bomb-drop aircraft relative to the point of weapon detonation. Project 5.2 also tested aircraft fabric covering by attaching aircraft panels with various fabric covering to the lower wing panels of two T-33s used during Shot ENCORE in Project 6.11, Indoctrination of Tactical Air Command Aircrews in the Delivery and Effects of Atomic Weapons (159; 207).

Project 5.2 personnel were assisted by individuals from the following agencies (159):

- Air Force Special Weapons Center
- Naval Radiological Defense Laboratory
- Signal Corps Engineering Laboratories.

Project 5.3, Blast Effects on B-36 Type Aircraft in Flight, was designed to obtain data on the blast response of a B-36D aircraft flown near a nuclear detonation. The test aircraft was the same B-36D aircraft used for similar testing during Shots MIKE and KING of Operation IVY in the Pacific, and the information gained at Shot ENCORE was to supplement the data obtained at those events. In particular, this project studied more fully the blast response of the aft fuselage and the horizontal stabilizer. Information for this project was obtained from instruments placed throughout the aircraft. A crew of ten from the Strategic Air Command (SAC) flew the aircraft in an orbit identical to that flown by the aircraft that dropped the ENCORE device, except that it was above and in front of the drop aircraft (205).

4.1.6 Program 6: Test on Service Equipment and Operations

Program 6: Test on Service Equipment and Operations, had two basic objectives:

- To evaluate field tests of radiation detection instruments and associated electronic equipment
- To evaluate methods for determining the ground zero, height of burst, and yield of a nuclear detonation.

In addition to testing radar and radiation-detecting equipment, the program trained Air Force personnel in the delivery of nuclear weapons. Table 4-8 lists the projects conducted during Operation UPSHOT-KNOTHOLE as part of Program 6 (87-88; 98).

Project 6.2, Indirect Bomb Damage Assessment (IBDA) Phenomena and Techniques, was performed at all shots to confirm indications that radar could be used to determine the three IBDA parameters: ground zero, height of burst, and yield of a nuclear detonation. The project involved both ground and air personnel.

Table 4-8: MILITARY EFFECTS GROUP PROJECTS CONDUCTED AS PART OF PROGRAM 6 DURING OPERATION UPSHOT-KNOTHOLE

Project	Title	Project Objectives	Shots	Participants
6.2	IBDA Phenomena and Techniques	To obtain scientific and experimental radar to assist in the development of an IBDA system	All	Wright Air Development Center; Vitro Corporation
6.3	Interim IBDA Capabilities of Strategic Air Command	To determine by tests under field conditions current IBDA capabilities	ANNIE, NANCY, DIXIE, BADGER, SIMON, ENCORE, HARRY, GRABLE, CLIMAX	Strategic Air Command
6.4	Evaluation of Chemical Dosimeters	To assess the capabilities of personnel dosimeters	SIMON, HARRY	Chemical and Radiological Laboratories
6.7	Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations	To measure the pulse shape, polarization, amplitude and duration of radio frequency signals due to nuclear detonations	All	Signal Corps Engineering Laboratories
6.8	Evaluation of Military Radiac Equipment	To evaluate under actual field conditions all existing radiac rate meters and dosimeters constructed for military use	ANNIE, NANCY, DIXIE, BADGER, SIMON, ENCORE, HARRY	Signal Corps Engineering Laboratories; Bureau of Ships
6.8a	Initial Gamma Exposure versus Distance	To use reliable film dosimeters for evaluation of experimental dosimeters	ANNIE, NANCY, RUTH, RAY, BADGER, SIMON, ENCORE, HARRY, GRABLE	Signal Corps Engineering Laboratories
6.9	Evaluation of Naval Airborne Radiac Equipment	To evaluate airborne radiac equipment	ANNIE, NANCY, RUTH, BADGER, SIMON	Navy Bureau of Aeronautics
6.10	Evaluation of Rapid Aerial Radiological Survey Techniques	To improve the procedures used during the JANGLE and SNAPPER Series in making aerial radiological surveys	ANNIE, NANCY, BADGER, SIMON, ENCORE, HARRY, GRABLE	Signal Corps Engineering Laboratories
6.11	Indoctrination of Tactical Air Command Air Crews in the Delivery and Effects of Atomic Weapons	To provide realistic operational training for TAC aircraft crews on the effects of blast, thermal, and nuclear radiation	DIXIE, ENCORE	Tactical Air Command; Air Research and Development Command
6.12	Determination of Height of Burst and Ground Zero	To evaluate artillery sound ranging equipment	All	Signal Corps Engineering Laboratories; Army Field Forces Board #1
6.13	Effectiveness of Fast Scan Radar for Fireball Studies and Weapons Tracking	To evaluate the effectiveness of a new fast scan X-band radar for phenomenology studies of nuclear detonations	SIMON, ENCORE, HARRY, GRABLE	Naval Electronics Laboratory

At five tower shots, ground crews operated 15 receiver stations located in a line at least 11 kilometers from ground zero. A truck with a synchronizing receiver and radar transmitter was at least ten kilometers from ground zero. At all 11 shots, a radar set was manned west of the Control Point, 13 to 23 kilometers from the various ground zeros.

B-29 aircraft from Kirtland AFB equipped with the latest IBDA systems orbited at altitudes ranging from 19,000 to 25,000 feet to the south, east, and north of the ground zeros (151; 186).

Project 6.3, Interim IBDA Capabilities of Strategic Air Command, like Project 6.2, evaluated IBDA systems installed in bomber and fighter aircraft flying simulated strike and support missions over a target. The aircraft recorded data essential for determining ground zero, burst height, and yield of a nuclear detonation.

There were seven to 20 aircraft with crews of 33 to 212 at each of nine detonations. Fighter aircraft operated from George AFB, California. The bombers staged from Travis AFB, California; Carswell AFB, Texas; McDill AFB, Florida; Castle AFB, California; Hunter AFB, Georgia; Fairchild AFB, Washington; and Roswell AFB, New Mexico (154).

Project 6.4, Evaluation of Chemical Dosimeters, was fielded by the Chemical and Radiological Laboratory of the Army Chemical Center at SIMON and HARRY. This project was closely coordinated with Projects 6.8 and 29.1. Data from these two projects were used by Project 6.4 personnel to evaluate the E-1 Tactical Dosimeter and several other personnel dosimeters under development. Before the detonation, personnel affixed the dosimeters to stations consisting of a frame and a plate. Each station was covered by a thermal and shock shield. In addition, 12 tactical

dosimeters were given to Desert Rock troops to test field usability during Shot SIMON (59).

Project 6.7, Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations, consisted of two parts. The first part measured amplitude, duration, and polarization of the pulse of the electromagnetic radiation. The second part detected and recorded electromagnetic signals emitted by nuclear devices prior to the nuclear detonation. This second part, a continuation of research begun earlier by the Office of Naval Research, was conducted primarily at CLIMAX, with only limited participation at Shots DIXIE through GRABLE (75).

Project 6.8, Evaluation of Military Radiac Equipment, and Project 6.8a, Initial Gamma Exposure versus Distance, were performed by the Signal Corps Engineering Laboratories and the Bureau of Ships. They were assisted by Air Force and Navy personnel. Project 6.8 was designed to test radiac instruments in initial and residual radiation fields. More specifically, the study was developed to (152):

- Test and evaluate existing or experimental radiac survey equipment and dosimeters
- Evaluate the adequacy of modifications of equipment stemming from previous tasks
- Provide certain radiological safety support functions to Desert Rock troops and aircrews of participating aircraft.

The purpose of Project 6.8a was to (158):

- Use reliable National Bureau of Standards dosimeters to provide a basis for evaluating other types of dosimeters used by Project 6.8
- Document initial gamma radiation exposure data for the nuclear devices tested
- Provide support gamma dosimetry measurements required for the evaluation of other radiation and biomedical studies (such as Projects 6.4 and 29.1).

Project personnel placed experimental and standard dosimeters at portable stations designed with aluminum thermal and blast shields. Upon recovery, the experimental dosimeters were compared to film exposed in National Bureau of Standard film holders.

Another part of the project involved about 150 personnel qualified in using radiac instruments and surveying radiation areas. To evaluate radiac instruments, these personnel, working in groups of 12 to 15, conducted ground surveys. Personnel were rotated on a weekly basis to avoid overexposures. The participants' observations and data were used with maintenance, repair, and modification records to evaluate the dosimeters (152; 158).

Project 6.9, Evaluation of Naval Airborne Radiac Equipment, was designed to evaluate airborne radiac equipment, including aerial ground survey equipment, automatic recording dosimeters, and gamma dosimeters that were designed to determine the radiation intensity on the ground. Personnel compared survey results taken by Project 6.8 personnel on the ground with the intensities measured by equipment in the aircraft. The equipment was examined for use in carrier-based aircraft to provide assault troops with information on contaminated areas.

In conducting the project, a P2V-2 aircraft operating from Kirtland AFB flew a holding pattern close to the shot area while waiting for the dust cloud to dissipate. When cleared to enter the area, the aircraft made repeated runs over the contaminated territory at various altitudes, and the crew recorded the radiation intensities shown on the aerial ground survey equipment. Telemetering units were dropped at ANNIE and NANCY to determine if the radiation measured by the dropped units could be read on instruments within the aircraft. Project 6.9 was conducted at five shots by the Navy Bureau of Aeronautics (230).

Project 6.10, Evaluation of Rapid Aerial Radiological Survey Techniques, was fielded to improve the radiological aerial survey procedures used during Operations BUSTER-JANGLE and TUMBLER-SNAPPER. The effect of the aircraft on radiac instrument readings taken inside the aircraft was also studied. The project, which was conducted at six shots, used an Air Force C-45 aircraft, a Marine HRS-2 helicopter, or an Army H-23 helicopter. Film badges were placed at various locations opposite one another on the interior and exterior of the aircraft. For each shot, the aircraft flew a cloverleaf pattern centered over a predetermined point (204).

Project 6.11, Indoctrination of Tactical Air Command (TAC) Air Crews in the Delivery and Effects of Atomic Weapons, was designed to inform TAC aircrews about the effects of blast, thermal, and nuclear radiation that could be encountered in the delivery of nuclear weapons. The activity also trained TAC reconnaissance pilots in the techniques of photographing areas subjected to the effects of a nuclear detonation. Project 6.11 was conducted at Shots DIXIE and ENCORE. Before participating in Project 6.11, 29 pilots and four alternates witnessed the detonation of Shot NANCY to indoctrinate them in the flash effects of a nuclear detonation (207).

Project 6.12, Determination of Height of Burst and Ground Zero, was fielded at all UPSHOT-KNOTHOLE events except Shot CLIMAX by the Signal Corps Engineering Laboratories and Army Field Forces Board #1. The objective was to evaluate the capability of (231):

- Artillery sound-ranging equipment to locate ground zero
- Seismic wave geophones to determine height of burst
- Flash-ranging cameras to determine height of burst and location of ground zero.

Personnel placed sound-ranging systems around the Camp Desert Rock area from 20 to 70 kilometers from the various ground zeros

and seismic geophones and flash-ranging cameras at various locations 13 to 16 kilometers from the ground zeros (231).

Project 6.13, Effectiveness of Fast Scan Radar for Fireball Studies and Weapons Tracking, was conducted at SIMON, HARRY, ENCORE, and GRABLE. The objective was to evaluate the effectiveness of a new fast scan X-band radar for phenomenology studies of nuclear detonations and to attempt to track the 280mm projectile at Shot GRABLE (155).

4.1.7 Program 7: Long-range Detection

The objective of Program 7, Long-range Detection, was to improve techniques for gathering information on nuclear events in foreign countries. The Program 7 experiments were designed to collect this information at remote locations. Calibration measurements were made within and close to the NPG. Four projects were conducted by the Air Force during Operation UPSHOT-KNOTHOLE, as shown in table 4-9 (87-88; 98).

Table 4-9: MILITARY EFFECTS GROUP PROJECTS CONDUCTED AS PART OF PROGRAM 7 DURING OPERATION UPSHOT-KNOTHOLE

Project	Title	Project Objectives	Shots	Participants
7.1	Electromagnetic Effects from Nuclear Explosions	To obtain information on the electromagnetic radiations produced by a nuclear detonation	All	Headquarters, Air Force*
7.3	Detection of Airborne Low Frequency Sound from Nuclear Explosions	To compare low frequency sounds produced by a nuclear detonation at remote field stations	All	Headquarters, Air Force*
7.4	Seismic Measurements	To conduct long-range recording of seismic waves produced by a nuclear detonation	All	Headquarters, Air Force
7.5	Calibration and Analysis of Close-in A-Bomb Debris	Analyze samples of the nuclear cloud to evaluate each nuclear device	All	Headquarters, Air Force; AFSWC

* Other participating agencies are listed in the text.

Project 7.1, Electromagnetic Effects from Nuclear Explosions, continued studies conducted during Operations BUSTER-JANGLE and TUMBLER-SNAPPER. The project was designed to obtain additional information on the electromagnetic radiation produced by a nuclear detonation. In conducting the study, project personnel monitored manned stations both onsite and offsite. The personnel were from the National Bureau of Standards, the Air Force Security Service, the Air Force Cambridge Research Center, and the Air Weather Service. Manned onsite locations were between 15 and 30 kilometers from the ground zeros of the 11 shots (198).

Project 7.3, Detection of Airborne Low Frequency Sound from Nuclear Explosions, was conducted to compare low frequency sounds produced by nuclear detonations at various remote field stations. These stations were located across the United States and around the world. The Signal Corps Engineering Laboratories operated stations in Alaska, Hawaii, Greenland, Japan, and Germany. The Naval Electronics Laboratory, the Signal Corps Engineering Laboratories, and the National Bureau of Standards manned the nine stations throughout the United States (200).

Project 7.4, Seismic Measurements, recorded the seismic waves produced by each detonation and compared them with the seismic waves recorded for the other shots in the series and previous nuclear events. Project 7.4 personnel operated one onsite station and several remote stations located throughout the midwestern and western United States and in Alaska. The onsite station was at UTM coordinates 843094, seven kilometers north of the BUSTER-JANGLE intersection (76).

Project 7.5, Calibration and Analysis of Close-in A-Bomb Debris, analyzed samples of the cloud resulting from the detonations to evaluate various parameters of each nuclear

device. For this project, aircraft took gaseous and particulate samples of each cloud (94; 222). Because these activities were performed by AFSWC personnel, they are detailed in section 4.4, Air Force Special Weapons Center Support Missions at Operation UPSHOT-KNOTHOLE.

4.1.8 Program 8: Thermal Measurements and Effects

Program 8, Thermal Measurements and Effects, documented the thermal characteristics of the military effects shots, ENCORE and GRABLE, and obtained data on the thermal characteristics of the nine other test detonations. Effects of thermal radiation are sometimes evident beyond the range of blast and nuclear radiation effects and include skin burns and the initiation of fires. The 14 projects of Program 8, shown in table 4-10, were designed to study these problems. Two types of protection against burns were used: clothing and smoke screens. The study of fires initiated by nuclear devices provided information for predicting the likelihood that these devices would start fires in urban areas (87-88; 98).

Project 8.1a, Effects of Thermal and Blast Forces from Nuclear Detonations on Basic Aircraft Structures and Components, was developed to study the capabilities of weapons-delivery aircraft and to establish design criteria for future weapons-delivery aircraft. Project personnel placed instrumented aircraft structures and components at various distances from ground zero (214).

Project 8.1b, Additional Data on the Vulnerability of Parked Aircraft to Atomic Bombs, was designed to determine the protection provided by thermal radiation shields and strong tie-downs to parked aircraft. Before the detonation, personnel placed a B-17, B-29, B-45, F-86, and four F-47s at various distances from

Table 4-10: MILITARY EFFECTS GROUP PROJECTS CONDUCTED AS PART OF PROGRAM 8 DURING OPERATION UPSHOT-KNOTHOLE

Project	Title	Project Objectives	Shots	Participants
8.1a	Effects of Thermal and Blast Forces from Nuclear Detonations on Basic Aircraft Structures and Components	To determine thermal and blast effects on aircraft components	RUTH, RAY, BADGER, SIMON, ENCORE	Wright Air Development Center; Division of Research, University of Dayton
8.1b	Additional Data on the Vulnerability of Parked Aircraft to Atomic Bombs	To determine thermal and blast effects on parked aircraft	ANNIE, RUTH, SIMON, ENCORE, HARRY, GRABLE	Wright Air Development Center
8.2	Measurement of Thermal Radiation with a Vacuum Microphone	To evaluate a microphone used to measure thermal radiation	All except CLIMAX	Air Force Cambridge Research Center
8.4.1	Protection Afforded by Operational Smoke Screens against Thermal Radiation	To evaluate the effectiveness of a white smoke screen as a thermal shield	ENCORE, GRABLE	Army Chemical Center; Naval Radiological Defense Laboratory
8.4.2	Evaluation of a Thermal Absorbing Carbon Smoke Screen	To evaluate the effectiveness of a black smoke screen as a thermal shield	GRABLE	Army Chemical Center; Naval Radiological Defense Laboratory
8.5	Thermal Radiation Protection Afforded Test Animals by Fabric Assemblies	To evaluate the thermal protection provided by clothing	NANCY, ENCORE, GRABLE	Quartermaster Research and Development Laboratories; Walter Reed Army Medical Center
8.6	Performance Characteristics of Clothing Materials Exposed to Thermal Radiation	To evaluate thermal effects on field clothing	ENCORE, GRABLE	Quartermaster Research and Development Laboratories
8.9	Effects of Thermal Radiation on Materials	To develop a laboratory technique for evaluating the thermal protection provided by clothing	ENCORE, GRABLE, CLIMAX	Naval Material Laboratory
8.10	Physical Characteristics of Thermal Radiation from an Atomic Bomb Detonation	To supply data on the thermal characteristics of a nuclear detonation	RUTH, DIXIE, ENCORE, GRABLE, CLIMAX	Naval Radiological Defense Laboratory
8.11a	Incendiary Effects on Building and Interior Kindling Fuels	To evaluate the susceptibility of interior building materials to primary fires produced by a nuclear detonation	ENCORE, GRABLE	Forest Service, Forest Products Laboratory
8.11b	Ignition and Persistent Fires Resulting from Atomic Explosions—Exterior Kindling Fuels	To evaluate the susceptibility of exterior urban structures to primary fires produced by a nuclear detonation	DIXIE, ENCORE, GRABLE	Forest Service, Division of Fire Research
8.12a	Sound Velocities near the Ground in the Vicinity of an Atomic Explosion	To measure the velocity of sound near ground surfaces following a nuclear detonation	SIMON, ENCORE, GRABLE	Naval Electronics Laboratory
8.12b	Supplementary Pressure Measurements	To determine whether intense thermal radiation over a surface can produce a blast wave	ENCORE, GRABLE	David Taylor Model Basin
8.13	Study of Fire Retardant Paints	To evaluate the thermal effects of a nuclear detonation on materials painted with fire retardant paint	ENCORE	Engineer Research and Development Laboratories; Bureau of Yards and Docks

ground zero at six shots. The aircraft were instrumented, and all except the B-29 had been used in previous tests (101).

Project 8.2, Measurement of Thermal Radiation with a Vacuum Microphone, was conducted at all shots except CLIMAX to evaluate a vacuum microphone used to measure the thermal radiation produced by a nuclear detonation. In fielding the project, personnel manned two vans containing recording equipment. The vans were located within view of the detonations, at ranges of approximately 11 to 23 kilometers from each ground zero (47).

Project 8.4.1, Protection Afforded by Operational Smoke Screens against Thermal Radiation, was fielded at Shot GRABLE by the Army Chemical Center. Although this project had been planned for ENCORE and all instrumentation had been set up, wind conditions resulted in a last-minute cancellation of this project. The project rescheduled for Shot GRABLE was a limited experiment, using a single instrumentation station. The objective was to measure the reduction in thermal radiation behind a white smoke screen. The smoke screen can be seen in figure 4-1. Before the shot, personnel placed smoke pots and an instrumentation station in the area around ground zero. Following the detonation, they recovered the instruments. Figure 4-3 shows a project participant checking smoke generators for use in the project (93).

The objective of Project 8.4.2, Evaluation of a Thermal Absorbing Carbon Smoke Screen, was to determine changes in the blast wave as it moved over a heated air layer created by carbon black smoke from smoke pots. The black smoke in the photograph of the GRABLE detonation in figure 4-1 is from this project. Before the detonation, personnel placed smoke pots and thermal- and blast-measuring instruments around ground zero. They retrieved the instruments after the detonation (92).

Figure 4-3: PROJECT 8.4.1 AT SHOT GRABLE, PARTICIPANT TESTING SMOKE GENERATORS ON FRENCHMAN FLAT

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Project 8.5, Thermal Radiation Protection Afforded Test Animals by Fabric Assemblies, was fielded at Shots NANCY, ENCORE, and GRABLE by the Army Quartermaster Research and Development Laboratories. They practiced the test at NANCY and then conducted the actual study at ENCORE and GRABLE. The purpose of this study was to evaluate the skin burn protection afforded by service and experimental clothing. Before the shot, project participants placed animals in uniforms or behind open and fabric-covered portholes at various distances from ground zero. After the shot, they retrieved the animals (195).

Project 8.6, Performance Characteristics of Clothing Materials Exposed to Thermal Radiation, was closely associated with Project 8.5. The objectives were to characterize further the thermal effects of nuclear detonations on standard and experimental field clothing. In contrast to Project 8.5, this project used instruments rather than animals. Before the shot, participants placed fabric and packing materials at various locations, including the same areas used for Project 8.5, and retrieved them after the shot (97).

Project 8.9, Effects of Thermal Radiation on Materials, studied the thermal radiation produced at various distances from a nuclear detonation. Personnel measured the spectrum of the thermal radiation at different ranges, the amount of thermal energy transferred through layers of clothing, and the effects of the detonation on a plastic skin simulant. They evaluated the skin simulant for use in future cloth-barrier studies. The Naval Material Laboratory fielded this project at Shots ENCORE, GRABLE, and CLIMAX (187).

Project 8.10, Physical Characteristics of Thermal Radiation from an Atomic Bomb Detonation, supplied additional data on the basic thermal radiation characteristics of nuclear devices. Although the project was conducted at Shot RUTH, no reliable data

were obtained because instruments failed and the shot produced a smaller yield than expected. At DIXIE, ENCORE, GRABLE, and CLIMAX, personnel placed instruments at various ground locations before the shot. At DIXIE and ENCORE, they also placed devices to measure thermal radiation on several aircraft operating for other projects (109).

Project 8.11a, Incendiary Effects on Building and Interior Kindling Fuels, was fielded by the Forest Products Laboratory, Forest Service, Department of Agriculture. The project was designed to study the vulnerability of urban structures to primary fires produced by nuclear detonations. The study focused on materials that were either part of a building or were found within a building. Before Shot ENCORE, personnel placed furniture in two block houses and materials outside of three small frame houses specially constructed for the project. For both Shots ENCORE and GRABLE, personnel placed wooden racks with materials such as newspapers, weeds, and rags at various distances from ground zero. They returned after each shot to inspect damage (52).

Project 8.11b, Ignition and Persistent Fires Resulting from Atomic Explosions: Exterior Kindling Fuels, was fielded by the Division of Fire Research, Forest Service, Department of Agriculture. Its purpose was to study the vulnerability of urban structures and transient kindling, such as newspapers and wrapping paper, to primary fires produced by nuclear detonations. Project 8.11b focused its investigation on exterior kindling fuels found in urban areas. For this project, personnel placed materials in wooden racks and various items in cars and around fence sections and wall slabs that had been built for the project. For a study of fire buildup, a helicopter entered the area after the detonation to report fires. A recovery party returned after each shot to inspect damage (212).

Project 8.12a, Sound Velocities near the Ground in the Vicinity of an Atomic Explosion, had two objectives: to measure sound velocities near the surface before the arrival of the shock wave and to examine sound velocities produced over white and black smoke. The second objective was pursued in conjunction with Projects 8.4.1 and 8.4.2 at Shots ENCORE and GRABLE. Wind conditions caused the cancellation of the white smoke test at ENCORE, for both Projects 8.12a and 8.4.1. Both white and black smoke tests were conducted at GRABLE (182).

Project 8.12b, Supplementary Pressure Measurements, was conducted to determine whether intense thermal radiation over a surface could generate a precursor shock wave. Before ENCORE, participants placed test panels of different thermal properties and pressure gauges at various distances from ground zero. The pressure gauge data were recorded. After ENCORE, personnel retrieved the data. The panels and instrumentation were repaired before Shot GRABLE (46).

Project 8.13, A Study of Fire Retardant Paints, was fielded at ENCORE to study the thermal effects of nuclear detonations on surfaces treated with fire retardant paints. Personnel instrumented and placed painted panels at various field locations. After the shot, they inspected the panels (185).

4.1.9 Program 9: Technical Photography

Program 9, Technical Photography, had two primary objectives (88; 98):

- To provide photographs and motion picture coverage of Operation UPSHOT-KNOTHOLE for technical purposes
- To develop a soil stabilizing agent to control dust raised following nuclear tests.

As table 4-11 indicates, three projects were conducted as part of Program 9 (88; 98).

Table 4-11: MILITARY EFFECTS GROUP PROJECTS CONDUCTED AS PART OF PROGRAM 9 DURING OPERATION UPSHOT-KNOTHOLE

Project	Title	Project Objectives	Shots	Participants
9.1	Technical Photography	To provide still and motion picture photography for all test group projects at UPSHOT-KNOTHOLE as requested	All	EG&G; Signal Corps Pictorial Center; Air Force Lookout Mountain Laboratory
9.6	Production Stabilization	To develop one or more soil stabilizing agents that would reduce the dust levels in Frenchman Flat area following a nuclear burst, so that burst could be photographed	ENCORE, GRABLE	Waterways Experiment Station; Engineer Research and Development Laboratories; Ohio River Division
9.7	Experimental Soil Stabilization	To develop one or more soil stabilizing agents that would reduce dust levels in Frenchman Flat area following a nuclear burst, so that burst could be photographed	ENCORE, GRABLE	Waterways Experiment Station; Engineer Research and Development Laboratories; Ohio River Division

Project 9.1, Technical Photography, was conducted at all shots by EG&G and by personnel from the Army Signal Corps Pictorial Center and the Air Force Lookout Mountain Laboratory. Twenty-three Signal Corps officers and five enlisted Air Force personnel were assigned to work directly with EG&G. The objective was to provide both still photographs and motion pictures of the preshot and postshot stages of various Military Effects Group projects. Motion pictures were taken from unmanned steel photo-towers six to 25 feet high or from photography trailers.

After participants installed the cameras at the stations, they covered the cameras with plastic bags to protect them from dust. Before the shot, personnel removed the plastic bags and loaded film into the cameras, which were then tested. The same project personnel who loaded the cameras recovered the film on

shot-day. EG&G processed all film either in Las Vegas or Los Angeles. Still and motion picture photography was also conducted before and after detonations for many of the projects (108).

While Project 9.1 was concerned with photographing the technical aspects of projects and detonations, personnel from the Air Force Lookout Mountain Laboratory photographed the detonation and some of the Military Effects Projects for documentary purposes. According to the weapons test report for Project 9.1, the documentary photography was separate from Project 9.1. The Lookout Mountain Laboratory personnel established and manned camera stations in various areas during most of the shots and photographed the detonations from a C-47 aircraft (108).

Project 9.6, Production Stabilization, and Project 9.7, Experimental Soil Stabilization, were conducted to find a way to stabilize the soil in the Frenchman Flat area so that dust clouds formed by blast waves would not interfere with technical photography. These projects originated in September 1952 when AFSWP asked the Army Chief of Engineers to study ways of stabilizing the ground surface in Frenchman Flat to reduce dust levels caused by nuclear tests. The Special Engineering Branch, Engineer Research and Development Division, Office of the Chief of Engineers, directed both Projects 9.6 and 9.7. The projects were assigned to the Soils Division of the Waterways Experiment Station in Vicksburg, Mississippi. The Engineer Research and Development Laboratories and the Ohio River Division in Cincinnati, Ohio, were also asked to assist. The Engineer Research and Development Laboratories conducted laboratory heat testing of various samples of prepared soil-stabilizing agents. The Ohio River Division personnel prepared samples of soil and sand-cement stabilizing agents and conducted some laboratory testing. The Waterways Experiment Station coordinated this work and, in addition, conducted design tests on asphalt-stabilizing materials. The laboratory work was performed during the fall of

1952. By January 1953, a sand-cement stabilizer was chosen for experimental use in Nevada, and field work was begun by about mid-March 1953.

The construction was contracted to Reynolds Electrical and Engineering Company. More than 585,000 square meters of five-centimeter-thick sand-cement material were prepared in the Frenchman Flat test area at various distances from the intended ground zero of ENCORE and GRABLE. After each shot, project personnel evaluated the damage to the sand-cement areas (90; 220).

4.2 WEAPONS DEVELOPMENT GROUP PROGRAMS

Besides the AFSWP Field Command Military Effects Group, the JTO coordinated the activities of the Weapons Development Group. The experiments of this group were primarily conducted by two AEC civilian nuclear weapons design laboratories: the Los Alamos Scientific Laboratory and the University of California Radiation Laboratory. The two laboratories fielded eight programs including 36 projects during Operation UPSHOT-KNOTHOLE. DOD participation was limited to two programs, as indicated in table 4-12 (70):

- Program 13, Radiochemistry
- Program 18, Thermal Radiation Measurements.

The only Program 13 activity involving DOD personnel during UPSHOT-KNOTHOLE was AFSWC participation in Project 13.1, Radiochemistry Sampling. Because Project 13.1 was supported by AFSWC pilots and aircraft, it is discussed in section 4.4 of this chapter.

Table 4-12: WEAPONS DEVELOPMENT GROUP PROJECTS CONDUCTED DURING OPERATION UPSHOT-KNOTHOLE

Program Title \ Shot Names	ANNIE	NANCY	RUTH	DIXIE	RAY	BADGER	SIMON	ENCORE	HARRY	GRABLE	CLIMAX
Program 10, Gamma Ray Measurements	10.1 10.2a 10.2c	10.1 10.2a 10.2b	10.1 10.2a 10.2b 10.4	 10.2b 10.4	10.1 10.2a 10.3	10.1 10.2a 10.3 10.4	10.1 10.2a 10.4	10.1 10.2b 10.4	10.1 10.2a 10.2c 10.4	10.1 10.3 10.4	10.1 10.2b 10.3 10.4
Program 11, Simultaneity Investigations		11					11				
Program 12, Technical Photography	 12.1b 12.1c 12.1d 12.1e 12.1f 12.1h 12.2c 12.2d	 12.1b 12.1c 12.1d 12.1e 12.1f 12.1h 12.2b 12.2c	 12.1b 12.1c 12.1d 12.1e 12.1f 12.1h 12.2c 12.2d	12.1a 12.1b 12.1c 12.1d 12.1e 12.1f 12.1h	 12.1b 12.1c 12.1d 12.1e 12.1f 12.1h 12.3	 12.1b 12.1c 12.1d 12.1e 12.1f 12.1h	 12.1b 12.1c 12.1d 12.1e 12.1f 12.1h 12.2a 12.2b 12.2c	12.1a 12.1b 12.1c 12.1d 12.1e 12.1f 12.1h	 12.1b 12.1c 12.1d 12.1e 12.1f 12.1h 12.2c 12.3	12.1a 12.1b 12.1c 12.1d 12.1e 12.1f 12.1h	12.1a 12.1b 12.1c 12.1d 12.1e 12.1f
Program 13, Radiochemistry	**13.1**	**13.1**	**13.1** 13.2	**13.1**	**13.1** 13.2	**13.1**	**13.1**	**13.1**	**13.1**	**13.1**	**13.1**
Program 14, XR Measurements	14								14		
Program 15, Electromagnetic Investigations	 15.3 15.4	15.2 15.3 15.4	 15.4	 15.4	 15.4	 15.4	 15.4	 15.4	15.2 15.3 15.4	 15.4	 15.3 15.4
Program 17, Neutron Measurements	17.1	17.1	 17.3 17.4 17.5	 	 17.4 17.5	17.1 17.2	17.1 17.2 17.3	 	 	17.1	
Program 18, Thermal Radiation	**18.1** **18.2** **18.3** **18.4** **18.6**	**18.1** **18.2** **18.3** **18.6**	**18.1** **18.2** **18.3** **18.6**	**18.1** **18.2** **18.3** **18.6**	**18.1** **18.2** **18.3** **18.6**	**18.1** **18.2** **18.3** **18.6**	**18.1** **18.2** **18.3** 18.5 **18.6**	**18.1** **18.2** **18.3** **18.6**	**18.1** **18.2** **18.3** **18.4** **18.6**	**18.1** **18.2** **18.3** **18.6**	**18.1**

Note: Bold print indicates projects with DOD participation.

Program 18, Thermal Radiation Measurements, consisted of six projects, all conducted by the Naval Research Laboratory of Washington, D.C. (70):

- Project 18.1, Total Thermal and Air Attenuation
- Project 18.2, Power versus Time
- Project 18.3, Spectroscopy
- Project 18.4, Light Absorption
- Project 18.5, Case Surface Brightness
- Project 18.6, Surface Brightness Investigations.

Of these six projects, detailed documentation has been located only for Project 18.3, Spectroscopy. The objective was to obtain information on spectral characteristics of light emitted from nuclear detonations by using spectrometers, which recorded the wavelength of light over time on film. Two spectrometers were located in Building 400, a permanent building near the Control Point at Yucca Pass. Three other spectrometers were located in a reinforced structure, which served as a mobile instrument station and was usually positioned about three kilometers from ground zero.

The two spectrometers at Building 400 were loaded with film, aligned, and checked for final operation about three hours before each scheduled shot. Project personnel remained in the building through the detonation. After the nuclear test, they turned off the equipment and removed the film from the spectrometers for processing.

At the mobile station, diesel generators powered the spectrometers. About seven hours before the scheduled shot, project personnel entered the trailer to load film and put the instruments into remote control operation. The station was then secured, and project personnel left the area. They recovered the film after the detonation (55; 77).

4.3 CIVIL EFFECTS GROUP PROGRAMS

Operation UPSHOT-KNOTHOLE was the first atmospheric nuclear weapons test series in which the Federal Civil Defense Administration participated. During UPSHOT-KNOTHOLE, the Civil Effects Group conducted eight programs including 36 projects. These activities were designed to predict the effects of nuclear detonations on civilian populations. Experiments included biomedical studies, tests of civilian shelters, radiation fallout studies, radiation defense training evaluation, and studies of the effects of fallout on drugs, animals, and food.

The weapons test reports are the primary source of information on the activities of the Civil Effects Group during Operation UPSHOT-KNOTHOLE. These reports deal primarily with the technical aspects of the programs and contain limited information on personnel activities. However, some of the reports indicate the names of participating groups in their introductory chapters. Such listings are the only sources available that identify DOD participation in the Civil Effects Group projects.

Civil Effects Group programs were numbered in consecutive order from 20 to 29 for Operation UPSHOT-KNOTHOLE. The Department of Defense participated in projects that were part of the following programs:

- Program 23, Biomedical Experiments
- Program 27, Fallout Studies in Near Areas
- Program 29, Dosimetry and Radiation Measurements.

Table 4-13 lists the projects with DOD participation and the shots at which the projects were conducted (70).

Program 23 investigated neutron and gamma radiation effects on animals and bacteria placed in or near AEC shelters. In general, the same Naval Radiological Defense Laboratory personnel

Table 4-13: CIVIL EFFECTS GROUP PROJECTS CONDUCTED DURING OPERATION UPSHOT-KNOTHOLE

Program Title \ Shot Names	ANNIE	NANCY	RUTH	DIXIE	RAY	BADGER	SIMON	ENCORE	HARRY	GRABLE	CLIMAX
Program 21, Civil Defense Effects Studies	21.1 21.2 21.3							21.3			
Program 22, FCDA Radiological Defense and Radiation Effects						22.2	22.1 22.2 22.3 22.4	22.2	22.4		
Program 23, Biomedical Experiments	**23.1** **23.2** **23.3** 23.4 23.5 23.6 23.7 23.8 23.9 23.10 23.11 23.12 23.13 23.14 23.15 23.16 **23.17**		**23.1** **23.2** **23.3** **23.17**	**23.1** **23.2** **23.3** **23.17**				**23.1** **23.2** **23.3** 23.8 23.12 23.14 23.15 **23.17**	**23.1** **23.2** **23.3** **23.17**	23.4 23.5 23.6 23.7 23.8 23.9 23.12 23.16 **23.17**	**23.1** 23.15 **23.17**
Program 24, AEC Shelter Structures	24.1 24.2 24.3					24.2		24.1 24.2	24.1 24.2 24.3	24.2	24.1 24.2
Program 26, Civilian Vehicle Tests	26.1 26.2		26.1 26.2	26.1 26.2				26.1 26.2		26.1	
Program 27, Fallout Studies in Near Areas		**27.1** 27.2	**27.1** 27.2	**27.1**		**27.1** 27.2	**27.1** 27.2				
Program 28, Radiation Telemetering System	28.1	28.1	28.1	28.1		28.1	28.1				
Program 29, Dosimetry and Radiation Measurements	29.2 29.3 29.4	29.3 29.4	29.3	**29.1** 29.3	**29.1** 29.3	**29.1**	**29.1** 29.3 29.4	**29.1**	**29.1** 29.2	**29.1**	**29.1** 29.2

Note: Bold print indicates projects with DOD participation.

conducted field operations for all Program 23 projects. Program 23 activities involving the DOD were (48; 232; 243):

- Project 23.1, Biological Effectiveness of Ionizing Radiation within Shelters
- Project 23.2, Bacteriological Studies on Animals Exposed to Neutron Radiation
- Project 23.3, Long-term Studies on Dogs Exposed to Primarily Neutron Irradiation in Shelters
- Project 23.17, Neutron Flux Measurements in AEC Group Shelters and Lead Hemispheres.

Program 27, Fallout Studies in Near Areas, was designed to study the fallout hazards to soil, plants, and animals located 16 kilometers or more from the site of a nuclear detonation. The one Program 27 activity involving DOD participants was Project 27.1, Distribution and Characteristics of Fallout at Distances Greater than Ten Miles from Ground Zero. Project personnel, including about 30 Navy enlisted personnel, placed and collected soil samples and conducted surveys in predicted and actual fallout areas from 16 to 128 kilometers from ground zero (206).

Program 29, Dosimetry and Radiation Measurements, developed and tested various types of dosimeters. In addition, the program studied radiation characteristics to aid in the design of more accurate recording instruments. The one program activity requiring DOD involvement was Project 29.1, Comparison and Evaluation of Dosimetry Methods Applicable to Gamma Radiation. Personnel of the Evans Signal Laboratory assisted the Atomic Energy Project, School of Medicine of the University of California at Los Angeles, by calibrating dosimeters in the field and processing them after exposure (227).

4.4 AIR FORCE SPECIAL WEAPONS CENTER SUPPORT MISSIONS

This section deals with the Air Force Special Weapons Center, which played a major role in many of the scientific and military test programs conducted at the NPG during Operation UPSHOT-KNOTHOLE. Although based at Kirtland AFB in Albuquerque, New Mexico, AFSWC used Indian Springs AFB, about 38 kilometers from Camp Mercury, as its principal staging area during the testing. AFSWC provided many of the aircraft and personnel required for the airdrop, cloud sampling, courier missions, cloud tracking, aerial surveys, and other air support. AFSWC air and ground participants in UPSHOT-KNOTHOLE numbered over 400 at Indian Springs AFB and about 2,000 at Kirtland AFB. AFSWC mission participation is summarized in table 4-14 (94; 105).

The principal AFSWC unit involved in Operation UPSHOT-KNOTHOLE was the 4925th Test Group (Atomic), which exercised operational control over all military aircraft participating in the test series, provided the delivery aircraft, the sampling aircraft, the B-25s for cloud-tracking, helicopters for aerial surveys, and ground support for other test participants such as the Air Weather Service and the Wright Air Development Center. Previously, the 4925th, at the test site on a temporary-duty, rotational basis, had provided the necessary personnel, aircraft, maintenance, and operational planning for sampling. In February 1953, the 4925th formed the Operations Unit Number One (Test) (Provisional) to coordinate sampling operations.* The Operations Unit trained other pilots from the 4925th Test Group and from the Strategic Air Command in sampling techniques. It also developed the F-84 sampler into the mainstay aircraft of sampling operations. This forward element of the 4925th consisted of 24 officers and 121 enlisted men (94; 105).

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*Later the 4926th Test Squadron

Table 4-14: AFSWC MISSION SUPPORT AT OPERATION UPSHOT-KNOTHOLE

Mission	Project Supported	ANNIE	NANCY	RUTH	DIXIE	RAY	BADGER	SIMON	ENCORE	HARRY	GRABLE	CLIMAX
Airdrop Delivery					●				●			●
Cloud Sampling	7.5	●	●	●	●	●	●	●	●	●	●	●
	13.1	●	●	●	●	●	●	●	●	●	●	●
Courier Sample Return	2.1				●				●		●	
	2.3								●	●	●	
	4.1								●			
	6.2	●	●	●	●	●	●	●		●		●
	7.5	●	●	●	●	●	●	●	●	●	●	●
	13.1	●	●	●	●	●	●	●	●	●	●	●
	13.2			●		●	●			●		
	17.1	●	●			●	●	●			●	
	23.4	●										
Cloud Tracking		●	●	●	●		●	●	●	●	●	●
Aerial Survey		●	●	●	●	●	●	●	●	●	●	●

The 4935th Air Base Squadron was based at Indian Springs AFB. Operation UPSHOT-KNOTHOLE was the first nuclear weapons testing series in which the 4935th participated. It provided regular airbase and radiological safety functions for nuclear testing and was organized solely to provide base support to the NPG, to the Test Manager, and to participating units. In addition, the 4935th furnished aircrews for security-sweep missions over the NPG and emergency air evacuation missions for the Test Manager. At the beginning of Operation UPSHOT-KNOTHOLE in March 1953, the 4935th Air Base Squadron had a station complement of 15 officers and 382 enlisted men (94; 105).

The 4901st Support Wing, based at Kirtland AFB, augmented the 4935th Air Base Squadron at Indian Springs with personnel and equipment. It provided sample courier aircraft, C-47s and L-20s for aerial surveys, aircraft for the security sweep and liaison flights, and aircraft for shuttle and air evacuation as needed. Three groups of the 4901st Support Wing supplied additional services:

- 4905th Maintenance and Supply Group
- 4910th Air Base Group
- 4920th Medical Group.

The personnel strength of the 4901st Support Wing at the time of the series was 3,540, including 772 civilians (71-73).

The 4905th Maintenance and Supply Group was responsible for maintenance of aircraft used in UPSHOT-KNOTHOLE projects. The 4910th Air Base Group handled regular airbase functions and, through its Base Radiological Warfare Defense Unit, provided radiological safety services at Kirtland AFB. The 4920th Medical Group maintained crews on call who were trained to handle any emergencies (71-73).

The 55th Weather Reconnaissance Squadron provided aircrews and aircraft for cloud-tracking missions during Operation UPSHOT-

KNOTHOLE. This squadron was based at McClellan AFB, California, with elements detached to Kirtland AFB for the length of the series (94).

The Aircraft Participation Unit, located in the Air Operations Center at the Control Point in Yucca Pass, maintained operational control over all military aircraft flying in the area of the NPG during the operational phase of Operation UPSHOT-KNOTHOLE. During the series, the Aircraft Participation Unit consisted of five personnel from the 4925th Test Group (94).

Cloud Sampling

An important objective of Operation UPSHOT-KNOTHOLE was to obtain samples of fission products from nuclear detonations so that the yield and efficiency of the nuclear devices could be determined. The task of collecting samples of particulate and gaseous debris from the clouds resulting from the detonations was assigned to the Operations Unit Number One (Test) (Provisional), which used F-84G and B-29 aircraft to perform the sampling. The Operations Unit collected cloud samples for the Weapons Development Group and the Air Force (94; 105; 229).

The Weapons Development Group required particulate samples for analysis as part of its scientific programs. The 4925th Test Group pilots collected these samples on filter papers held by a grid in specially modified wing-tip tanks of F-84G aircraft. The aircraft contained valves that could be opened to allow the air to pass through the wing-tip tank and trap particulates from the cloud in the filter paper. A radiation-detecting meter located in the wing-tip tank and connected to an instrument in the cockpit indicated to the pilot the size and quality of the sample collected. After the sampling was completed, the aircraft returned to Indian Springs AFB, where the samples were removed and sent promptly by courier aircraft to LASL and UCRL for analysis (94; 105; 229).

Gaseous samples were collected using two methods: the F-84 aircraft used snap sampling and the B-29s used squeegee sampling. In snap sampling, air was forced into a polyethylene bag located in the nose section of the F-84. A valve that allowed air to enter the bag through a probe was opened and closed by a switch in the cockpit. At Indian Springs AFB, the snap samples were pumped from the bags into steel cylinders. Squeegee sampling was done by introducing air into a large cylinder and forcing the gas into smaller cylinders. These cylinders were removed from the aircraft after it landed. After the samples were removed, they were placed in courier aircraft and flown to laboratories (94; 105; 222; 229).

Headquarters, Air Force, required collection of both gaseous and particulate cloud samples. The sampling mission was done for Military Effects Group Project 7.5. Cloud samples were collected by a B-29, which was suited for the mission because its long-range capability enabled it to stay aloft near the cloud long enough to complete the sampling. The gaseous and particulate samples gathered in a single mission were distributed among UCRL, LASL, and Air Force scientists for analysis (94; 105; 222; 229).

The standard procedures for cloud sampling were as follows. Approximately 15 minutes before the detonation, a B-50 aircraft took off from Indian Springs AFB, climbed to an altitude of 20,000 feet, and circled about 30 kilometers south of the point of detonation until shot-time. This B-50, designated the sampler control aircraft, was manned by an aircraft commander, a pilot, a flight engineer, two scanners, a radio operator, a sampler controller, a scientific advisor from either LASL or UCRL, depending on which was the sponsor of the detonation, and a technical operations advisor. The sampler controller was an Air Force pilot who relayed the scientific advisor's instructions to each sampler pilot. The technical operations advisor was an AFSWC flight surgeon. After the detonation, the sampler control

aircraft followed and observed the formation and dissipation of the cloud. During this time, the scientific advisor evaluated the cloud structure and determined the cloud areas from which sampler aircraft would collect particulate and gaseous samples (94; 105; 229).

On advice from the sampler control aircraft, the Aircraft Participation Unit notified the sampler control aircraft of when to take off and approximately where the cloud sampling would occur. The samplers left Indian Springs AFB under radar surveillance, sometimes as long as two hours after a detonation. The flight engineer in the B-50 sampler control aircraft vectored the sampler aircraft to the approximate location of the B-50. As each sampling aircraft rendezvoused with the sampler control aircraft, it was directed to penetrate the cloud at various altitudes and locations to gather particulate and gaseous nuclear debris (94; 105; 229).

After the mission was completed, the sampler control aircraft provided the sampler aircraft with information on routes to take to avoid the cloud on the return to Indian Springs AFB. After the aircraft landed, the samples were removed and packaged for delivery to LASL, UCRL, or Air Force laboratories for analysis. The sampler control aircraft was the last aircraft to land (94; 105; 229).

The time spent in the test area by an F-84 sampler pilot was limited as his dose increased. Because the type of sampling performed by an F-84 aircraft required cloud penetration where peak intensity readings were as high as 80 R/h, each F-84 sampler pilot was closely monitored. Every F-84 aircraft sampler carried an integron, a specially designed instrument that permitted the pilot to make an immediate check of his accumulated dose and end his mission before reaching the maximum. In addition, film badges were placed about the cockpit and on the pilot. The

aircraft was also fitted with a ratemeter that indicated the peak intensity of radiation fields. Because of the high doses anticipated, two groups of F-84 sampler pilots were scheduled for UPSHOT-KNOTHOLE. The first group, who participated in the first five shots, was allowed a maximum dose of 3.9 roentgens. The second group, who flew in the next five shots, was also permitted an accumulation of 3.9 roentgens, but when Shot CLIMAX was added to the schedule, the limit was raised to 4.1 roentgens for the second group of sampler pilots (94; 105; 229).

During Shot ANNIE, analysis of the recorded exposures of the F-84 sampler pilots revealed that at least half of their doses were acquired during the return flight to base. AFSWC accordingly took three steps to reduce after-mission exposures. The first step involved polishing the aircraft skin so that radioactive particles would not adhere to the aircraft. This procedure reduced the after-mission exposure by about 35 percent. Another step consisted of lining the cockpits with lead sheets about 0.08 centimeters thick. Because of a delay in obtaining the lead lining for the cockpits, not all F-84 samplers were lead-lined until Shot RAY. No figures have been found indicating the effectiveness of this lead lining in reducing radiation exposures. The last step, discussed in section 5.2 of this report, was to outfit pilots with lead-glass vests. These measures substantially decreased the amounts of exposure received on the return flight. The sampler pilots in the first and second group began to accumulate 75 and 80 percent, respectively, of their doses while they were in the cloud. The new procedures enabled the pilots to spend more time in the cloud to collect samples (94; 105; 229).

Courier Service

The purpose of the AFSWC courier service, provided by the 4901st Support Wing, was to deliver radioactive samples and data from UPSHOT-KNOTHOLE research projects to laboratory facilities,

such as LASL, UCRL, the Naval Research Laboratory, and the Lovelace Medical Center.

AFSWC supplied C-47 and B-25 aircraft and crews for courier service for test group projects. A total of 48 courier sorties were flown during Operation UPSHOT-KNOTHOLE (71-73; 94).

Cloud Tracking

AFSWC and the Air Weather Service conducted cloud tracking. Its objective was to record the path of the cloud and to monitor its radiation intensity in order to expedite airway clearance for commercial aircraft by the Civil Aviation Administration. Cloud tracking was planned for all UPSHOT-KNOTHOLE events and was conducted at all but Shot RAY. A total of 27 sorties, using B-25 and B-29 aircraft, were flown in the cloud-tracking program (94; 105; 229).

The number of DOD participants involved in the UPSHOT-KNOTHOLE cloud-tracking program is estimated to be 215. The B-25 tracker carried five AFSWC crew members, including one radiological safety monitor. The B-29 tracker carried ten crewmen, including a radiological safety monitor. The B-29 crews were from the 55th Weather Reconnaissance Squadron from McClellan AFB, California, temporarily based at Kirtland AFB. They probably rotated missions among the 50 Air Weather Service participants assigned duty at UPSHOT-KNOTHOLE (94).

Cloud-tracking procedures were standard for every shot, with some modifications caused by difference between the estimated and actual yield of a detonation. Flying at an approximate altitude of 12,000 feet, the B-25 aircraft tracked the lowest part of the cloud stem. One of two B-29 aircraft observed the cloud from its stem to its top. The B-50 sampler control aircraft tracked the top of the cloud and then left the area following the sampling aircraft. The second B-29 aircraft was held in reserve near the

cloud in case either the B-25 or the B-29 aircraft had a mechanical failure or the cloud had to be tracked for an extended period of time (94; 105; 118; 229).

After departing from Indian Springs AFB, the B-25 aircraft was in the vicinity of the test site at shot-time and followed the cloud by visual means as long as possible. When the cloud was no longer visible, highly sensitive air-conductivity and scintillation-counter instruments were used to detect the cloud (94; 105; 118).

The two B-29 aircraft followed the cloud to a distance of 320 to 965 kilometers from the point of detonation. To track the cloud, the aircraft flew near the leading edge or sides of the cloud, changed direction every two or three minutes as instruments aboard the aircraft gave measurable readings, and then turned away before actually penetrating the cloud. The position, time, altitude, and maximum intensity readings of the cloud were reported back to the Control Point, where the information was used to plot cloud dimensions and course (94; 105; 118).

Repeating this procedure throughout the mission, the cloud trackers determined the progress and extent of the cloud. The cloud was tracked until it dissipated or until the Test Manager directed the trackers to stop. The B-25 then returned to Indian Springs AFB, and the B-29s flew back to Kirtland AFB (94; 105; 118).

Aerial Surveys

Following each nuclear event, several support aircraft made low-altitude radiological surveys of the terrain in and around the NPG. These surveys helped determine when ground parties could safely enter the test area, and delineated the extent of offsite contamination. AFSWC provided several types of aircraft for this activity, including H-19 and H-5 helicopters and L-20

and C-47 airplanes. AFSWC crews operated the helicopters and airplanes for about three hours after the detonation or as long as required, up to 160 kilometers from ground zero (74; 94).

The standard operating procedure for aerial surveys was as follows. After each detonation, the helicopters and other aircraft were to take low-level surveys of the immediate target area to determine radiological hazards. The helicopters took off from the Control Point, and the fixed-wing aircraft took off from Indian Springs AFB (74; 94). The Test Manager determined the departure times of the various aircraft and patterns of flight. Radio contact with the Aircraft Participation Unit was mandatory during these missions.

CHAPTER 5

RADIATION PROTECTION AT OPERATION UPSHOT-KNOTHOLE

In addition to the thermal and blast phenomena associated with a conventional explosive device, a nuclear detonation produces ionizing radiation. To protect UPSHOT-KNOTHOLE participants from the radiation associated with the detonation of a nuclear device, Exercise Desert Rock V, the Joint Test Organization, and the Air Force Special Weapons Center each developed procedures to ensure the radiological safety of its members. The purpose of the various radiation protection procedures was to minimize the amount of ionizing radiation individuals were exposed to while performing the military and scientific activities conducted by Exercise Desert Rock V and the test groups. This chapter describes the specific tasks performed to protect UPSHOT-KNOTHOLE participants from unnecessary exposure to ionizing radiation.

Because each organization had different mission requirements, Exercise Desert Rock V, JTO, and AFSWC formed separate radiation protection staffs and plans; however, many of the procedures were similar and were performed by two or more of the groups. These procedures included (74; 120):

- Orientation and training: preparing radiation monitors for their work and familiarizing other participants with radiological safety procedures
- Personnel dosimetry: issuing and processing film badges and evaluating the gamma radiation exposures measured by these devices
- Use of protective equipment: providing protective equipment, including clothing and respirators
- Monitoring: performing radiological surveys and controlling access to all radiation areas

- Briefing: informing observers and project personnel of possible radiological hazards and the current status of radiation in the test area
- Decontamination: containing, removing, and disposing of contaminated material from personnel, vehicles, and equipment.

The Department of Defense supported the Test Manager in all onsite radiological safety procedures during Operation UPSHOT-KNOTHOLE. The 50th Chemical Service Platoon implemented safety procedures for Exercise Desert Rock V. The AFSWP Radiological Safety Support Unit implemented overall procedures for the JTO, which included the Military Effects Group, the Weapons Development Group, and the Civil Effects Group. In addition, the Radiological Safety Support Unit was involved in offsite radiological safety activities for areas within 320 kilometers of the Nevada Proving Ground (74; 120).

For Operation UPSHOT-KNOTHOLE, the Office, Chief of Army Field Forces (OCAFF), established criteria for positioning troops and troop observers at nuclear detonations, based partially upon the amount of prompt radiation troops were permitted to receive. These criteria were subject to AEC approval. All troops, except the volunteer officer observers at NANCY, BADGER, and SIMON, were adequately protected and far enough from the point of detonation to avoid overexposure from prompt gamma and neutron radiation (82).

5.1 RADIATION PROTECTION PLANS FOR EXERCISE DESERT ROCK V

The Army established safety criteria to protect Exercise Desert Rock V participants from the thermal, blast, and radiation effects of nuclear detonations. A directive dated 5 February 1953 from OCAFF addressed the physical and radiological safety of Desert Rock participants. The thermal, blast, and radiation

exposure limits established in this directive for Exercise Desert Rock V troops were (196):

- A maximum of one calorie per square centimeter of thermal radiation
- A maximum of five pounds per square inch of overpressure
- A maximum of six roentgens during Operation UPSHOT-KNOTHOLE, with no more than three roentgens of prompt radiation.

Based on these exposure limits, the Army set minimum distance criteria for the positioning of Exercise Desert Rock troops and observers. For example, according to these minimum criteria, troops in the open, observing a tower shot with a predicted maximum yield of 28 kilotons, would be positioned at least 10,060 meters from ground zero. Troops in trenches at such a shot would be positioned at least 3,390 meters from ground zero. These criteria, presented in table 5-1, applied to all Desert Rock troops except the volunteer officer observers, discussed later in this section (196).

OCAFF also authorized a special volunteer officer observer program for Exercise Desert Rock V. This program was designed to provide an opportunity for close observation of a nuclear detonation. OCAFF granted the Exercise Director authority to permit volunteers to position themselves in trenches closer to ground zero than the standard distance criteria described above. For the volunteer officer observer program, OCAFF authorized the following exposure limits (70; 120; 196):

- 10.0 roentgens per test, with no more than 5.0 roentgens of prompt radiation, and no more than a total of 25.0 roentgens during the entire exercise
- 8.0 pounds per square inch of overpressure
- 1.0 calorie per square centimeter of thermal radiation.

Table 5-1: ARMY SAFETY CRITERIA FOR PLACEMENT OF TROOPS DURING OPERATION UPSHOT-KNOTHOLE

FOR TOWER SHOTS

MAX. PREDICTED YIELD (kilotons)	DISTANCE FROM GROUND ZERO (meters) TROOPS IN OPEN	TROOPS IN TRENCHES
1 to 5	4,115	3,200
5 to 10	5,950	3,200
10 to 15	7,315	3,200
15 to 20	8,230	3,200
20 to 25	9,150	3,200
25 to 30	10,060	3,390
30 to 35	10,980	3,475
35 to 40	11,430	3,660

FOR AIRCRAFT-DELIVERED DEVICES

MAX. PREDICTED YIELD (kilotons)	DISTANCE FROM GROUND ZERO (meters) TROOPS IN OPEN	TROOPS IN TRENCHES
1 to 5	6,860	5,950
5 to 10	8,690	5,950
10 to 15	10,060	5,950
15 to 20	10,980	5,950
20 to 25	11,890	5,950
25 to 30	12,810	6,130
30 to 35	13,720	6,220
35 to 40	14,180	6,410

Table 5-1: ARMY SAFETY CRITERIA FOR PLACEMENT OF TROOPS DURING OPERATION UPSHOT-KNOTHOLE (Continued)

FOR 280mm CANNON-DELIVERED DEVICE

MAX. PREDICTED YIELD (kilotons)	DISTANCE FROM GROUND ZERO (meters)	
	TROOPS IN OPEN	TROOPS IN TRENCHES
1 to 5	5,030	4,120
5 to 10	6,860	4,120
10 to 15	8,230	4,120
15 to 20	9,150	4,120
20 to 25	10,060	4,120
25 to 30	10,980	4,300
30 to 35	11,890	4,390
35 to 40	12,350	4,580

Officer volunteers positioned themselves in trenches closer to ground zero than permitted for other Exercise Desert Rock V participants. There were volunteer officer observers at NANCY, BADGER, and SIMON; in each case, the location of the trench was based upon their calculation of a safe distance (120; 150).

5.1.1 Organization

Although AEC was responsible for the overall operation of the NPG, responsibility for the radiological safety of all Exercise Desert Rock V participants was delegated to the Exercise Director of Exercise Desert Rock. The Exercise Director assigned the operational aspects to the Radiological Safety Section, part of the Exercise Desert Rock G-3 Section. The Radiological Safety Section, whose operating unit was the 50th Chemical Service Platoon, implemented radiation protection procedures for all

Exercise Desert Rock V participants. The 505th Signal Service Group (Composite Company) provided photodosimetry services, including issuing, receiving, processing, and evaluating film badges. The Camp Desert Rock Surgeon evaluated the dosimetry records, recommending that individuals who had exceeded the 6.0 roentgen limit be barred from entry into test areas and that individuals approaching the 6.0 roentgen limit be curtailed in their activities within the test areas (120-121).

5.1.2 Orientation and Briefing

The Instructor Group, part of the Desert Rock G-3 Section, provided educational programs for observers and exercise and support troops to allay misconceptions about the effects of nuclear weapons. The Instructor Group presented a broad orientation, covering basic weapons characteristics and effects and the medical issues related to nuclear detonations and personal protection (120).

During the rehearsal of shot-day maneuvers, instructors conducted tours of the equipment and animal display areas for all personnel, discussing the predicted effects. In the hour before the shot, when personnel were in the trench area, the instructors presented information about the test area and safety procedures (120).

The Radiological Safety Section trained monitors in calibrating and operating radiac meters and assessing the exposure potential associated with different radiation intensities. Trainees from Camp Desert Rock support units were considered qualified monitors only when they had learned to use radiac meters to determine radiological safety. For example, they had to be able to calculate how long to stay within a radiation area without exceeding exposure limits. Students took both written and performance examinations at the completion of

their training. To ensure that previously trained monitors could interpret radiac readings, the Radiological Safety Section also provided a refresher course for experienced monitors from the 50th Chemical Service Platoon (120).

5.1.3 Personnel Dosimetry Procedures

Desert Rock personnel entering the forward area for Shots ANNIE and NANCY were instructed to wear film badges to monitor their exposure to ionizing radiation. After NANCY, however, the basis of issue for film badges changed to ease the workload of the 505th Signal Service Group. At the remaining events, except Shot BADGER, maneuver troops were issued one film badge per platoon and observers were issued one film badge per bus. The single film badge reading then represented the average exposure of each group. At BADGER, two film badges were issued per platoon (120; 122-123).

Cumulative film badge readings indicated the effectiveness of Desert Rock radiation protection procedures. However, only limited film badge data for Desert Rock troops have been recovered in spite of extensive archival searches. Therefore, radiation exposures for Desert Rock participants are derived from dose reconstruction, as discussed in chapter 6 (106).

Participants also carried pocket dosimeters, issued by the 505th Signal Service Group, to provide an instantaneous check on radiation exposure. Each troop platoon, monitoring team, and some of the observers carried one of these dosimeters, except at Shot BADGER where each company had two pocket dosimeters (120; 122-128).

5.1.4 Protective Equipment

The only available information on the use of protective equipment comes from operations orders and the Desert Rock Final Report of Operations. According to the operations orders, all Desert Rock troops entering the forward area on shot-days were supposed to carry a protective mask, which was worn on command. Although the troops wore no special protective clothing, they were required to keep their standard fatigues tucked securely into their boot tops and to keep their sleeves and collars tightly buttoned (120; 122-128).

5.1.5 Monitoring

Radiological ground surveys of the test area began after the shock wave passed or upon command of the Radiological Safety Officer. Two radiological survey teams, each consisting of a radiological safety monitor, a driver, and a radio operator from the 50th Chemical Service Platoon, proceeded from their parking area to their initial monitoring stations at the far end of the equipment and animal display. The teams followed the route shown in figure 5-1 through the test site until they located areas with radiation intensities of 0.01, 0.1, 1.0, 2.0, 2.5, and 5.0 R/h. They then radioed the intensity locations to the control trench for plotting on a map (120; 122-128).

One marking and posting team, consisting of one officer and six enlisted men, followed each survey team. Using stakes and marking tape, the team posted the "hot spots," which had been identified with intensities greater than 0.1 R/h. They also established the 2.5 R/h and the 5.0 R/h isointensity lines. The 2.5 R/h isointensity line was the forward limit for all observers and troops on foot within the test area until Shot HARRY. At Shots HARRY, ENCORE, and GRABLE, troops were permitted into areas with intensities greater than 2.5 R/h. At these shots, personnel were required to leave the radiation area before their pocket dosimeters registered 6.0 roentgens (120).

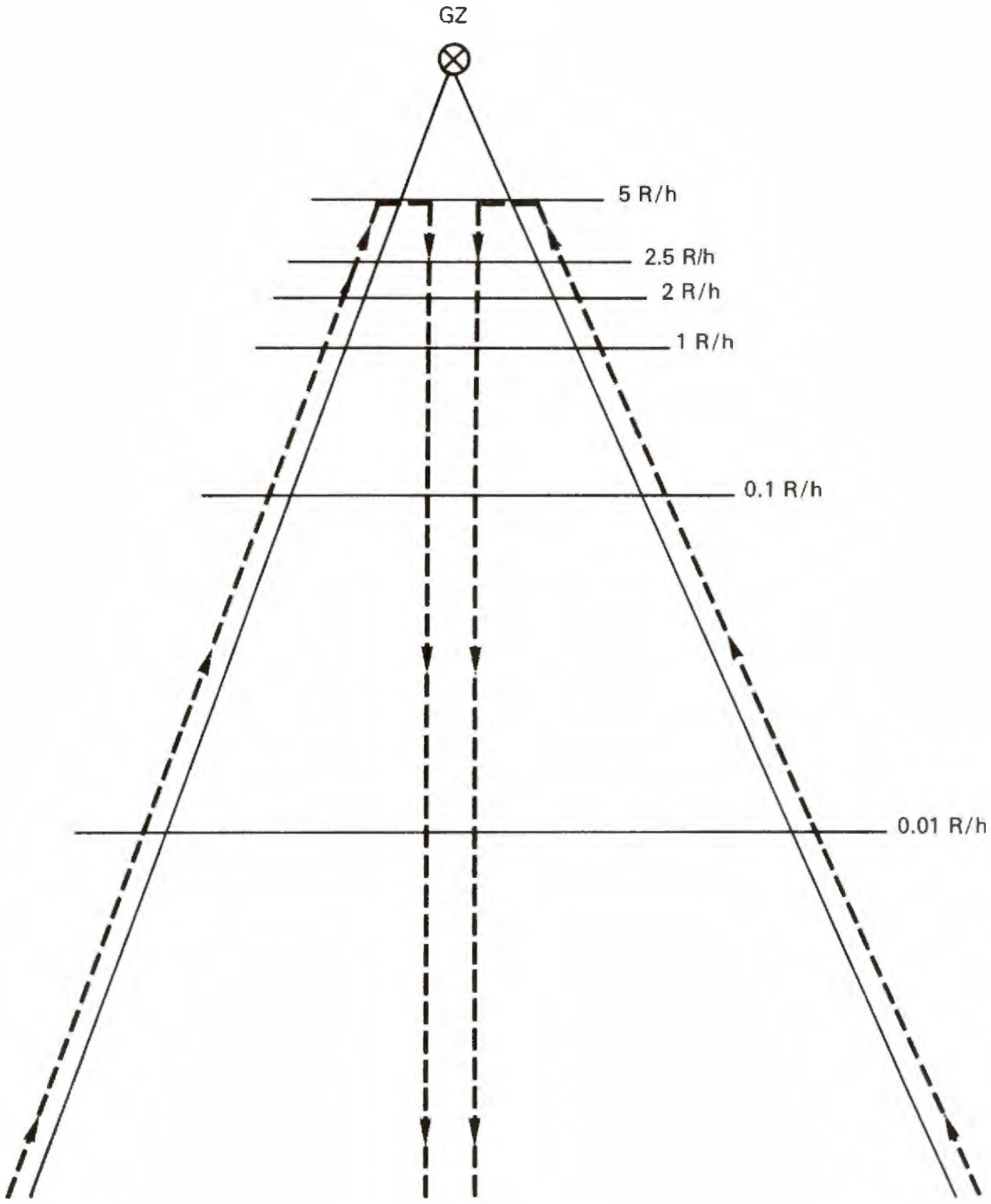

Figure 5-1: CHARACTERISTIC ROUTE OF RADIOLOGICAL MONITORING TEAMS THROUGH EQUIPMENT DISPLAY AREA

Another radiological survey team, consisting of a radiological safety monitor, an enlisted man serving as a driver, and a radio operator, proceeded about 140 meters in advance of the leading maneuver element to monitor the attack zones of the BCTs. Whenever a 2.5 R/h radiation intensity was measured, the radiological safety teams advised the BCT commander to halt the troop advance and either end the maneuver or take another route to the objective (120).

An additional survey team, with one radiological safety monitor and one enlisted man from the 50th Chemical Service Platoon serving as a driver, accompanied the commander of each BCT. These teams checked the radiation intensities found by the previous teams by patrolling across the zone of attack of the BCT. The survey teams monitored areas that had been measured as exceeding 1.0 R/h and reported their findings to the BCT commanders (120).

5.1.6 Decontamination

The objective of decontamination procedures for Exercise Desert Rock V was to ensure that no personnel or vehicles left the forward areas of the NPG carrying material, other than authorized test samples, contaminated in excess of established limits. For all shots except ANNIE and BADGER, this limit was 0.02 R/h above background levels of radiation. For personnel at Shot ANNIE, the limit for skin and hair was 0.001 R/h; for the outside surfaces of clothing, the limit was 0.007 R/h. The limit for the outside surfaces of vehicles was 0.01 R/h and for the inside surfaces, 0.002 R/h. For members of the 2d MCPAEB at Shot BADGER, the limit for skin was background level and the limit for clothing surfaces was 0.0015 R/h (120; 122-128).

The 50th Chemical Service Platoon operated the main decontamination facility about 900 meters north of the Control

Point at Yucca Pass, UTM coordinates 848888. The facility was the center of decontamination activities for both personnel and vehicles. The initial decontamination procedure involved brushing clothing, equipment, and vehicles to remove contaminated dust and debris. If the initial brushing failed to reduce radiation intensities to the established limit or lower, individuals showered and were provided with a change of clothing. Vehicles and equipment were either washed or quarantined until radiation intensities decayed to permissible levels (120).

After troops had entered contaminated areas either for maneuvers or to view damage effects displays, they returned to just outside the 0.02 R/h area to board buses for Camp Desert Rock. Before boarding a bus, however, personnel and equipment were swept with brooms to remove contaminated dust. The 50th Chemical Service Platoon then surveyed the personnel and vehicles for radiation using AN/PDR-27A survey meters that they held about five centimeters from the surfaces being surveyed. Further decontamination was necessary only when radiation intensities after the initial brushing were still above the limit (122-128).

Vehicles with radiation levels exceeding 0.02 R/h were driven onto a rock bed at the decontamination station and washed with detergent and water. After each washing, monitors measured the contamination level with portable survey instruments. If repeated washings did not reduce contamination to permissible levels, the vehicles were isolated until decay reduced contamination to 0.02 R/h or lower. When vehicles had been decontaminated to below the 0.02 R/h limit, they were returned to service at Camp Desert Rock (120; 122-128).

5.2 RADIATION PROTECTION PLANS FOR THE JOINT TEST ORGANIZATION

The Test Manager was responsible for the radiological safety of all members of the JTO who were at the NPG during Operation

UPSHOT-KNOTHOLE. The Radiological Safety Support Unit, composed of personnel from the Chemical Corps Training Center at Fort McClellan, Alabama, and headed by an officer appointed by AFSWP, conducted JTO onsite radiological safety operations (70; 74).

The Radiological Safety Support Unit worked within guidelines recommended by the AEC Division of Biology and Medicine and accepted by the Test Manager. The Division of Biology and Medicine established an exposure limit of 3.9 roentgens of gamma radiation for all personnel involved in JTO activities (74). Since the UPSHOT-KNOTHOLE operational period lasted almost 12 weeks, this 3.9 roentgen exposure limit was similar to the then-current 0.3 roentgen-per-week occupational exposure recommended by the National Council on Radiation Protection and the International Commission on Radiological Protection.

The operational responsibilities of the JTO onsite radiological safety organization were to (74):

- Provide radiac equipment and maintenance services
- Maintain dosimetry and records service for all organizations participating in the operation
- Provide training courses and guidance on radiological procedures and situations
- Conduct radiation surveys and plot isointensity maps
- Provide monitors to projects as needed
- Decontaminate personnel and vehicles.

The JTO records, particularly the Radiological Safety Operation report (74), do not distinguish between DOD personnel and personnel from the AEC, laboratories, or contractor organizations who were involved in JTO activities.

5.2.1 Organization and Responsibilities

DOD formed a new military organization to provide both onsite and offsite radiological safety services during Operation UPSHOT-KNOTHOLE. This organization, the Radiological Safety Support Unit, was activated at the Chemical Corps Training Center, Fort McClellan, Alabama. The onsite group consisted mostly of Chemical Corps Training Command personnel but was augmented with individuals from the Air Force and the Navy. The offsite group consisted of Public Health Service and LASL civilians, as well as members of the Radiological Safety Support Unit (70; 74).

The Radiological Safety Officer, who was appointed by AFSWP, managed both the onsite and offsite radiological safety activities. The Radiological Safety Officer implemented the Test Director's radiation protection policy, which concerned the radiological safety of all persons at or within a 320-kilometer radius of the NPG. This officer also supervised and coordinated all activities of Radiological Safety Support Unit and informed the Test Director of the radiological conditions both onsite and offsite. The Radiological Safety Officer was also responsible for coordinating radiological safety requirements with the Indian Springs AFB Radiological Safety Officer. The activities performed by the Radiological Safety Support Unit included (74):

- Furnishing all ground monitoring services for both scientific programs and radiological safety procedures within a 320-kilometer radius of the NPG
- Providing charts indicating the current radiological situation and maps showing onsite and offsite data obtained by ground and aerial surveys
- Issuing, processing, and maintaining records of all personnel dosimeters
- Operating personnel, vehicle, and equipment decontamination facilities

- Plotting the paths of the clouds resulting from the detonations and advising the Test Director on closing airways
- Packaging radioactive material and samples for shipment offsite.

To provide personnel for operations, the Chemical Corps Training Command temporarily assigned the 9778th Technical Support Unit to Camp Mercury as the Radiological Safety Support Unit. The Radiological Safety Support Unit maintained an approximate strength of 26 officers and 144 enlisted men. In addition, five Navy officers, five Navy enlisted men, five Air Force officers, and 13 Air Force enlisted men were on temporary assignment to Camp Mercury as augmentation personnel. Most of the personnel from the 9778th were assigned to the onsite operations group. The offsite operations group consisted of about ten enlisted personnel from the 9778th Technical Support Unit and one Chemical Corps officer, along with augmentation personnel, three LASL civilians, and 15 Public Health Service personnel (70; 74).

In early 1953, the Radiological Safety Support Unit at the NPG consisted of ten officers and nine enlisted men. By 15 February, the total strength had reached 22 individuals. The main body of the Support Unit arrived at the NPG on 1 March 1953, bringing the entire strength up to 180 personnel. Augmentation personnel arrived from 1 March through 17 March (74).

As originally planned, the radiological safety organization followed the chart shown in figure 5-2. After Shot NANCY, however, a reorganization occurred when the onsite operations officer left Camp Mercury. In the new organization, shown in figure 5-3, the commander of the Radiological Safety Support Unit assumed additional duties as the Onsite Operations Officer. The Control Section moved up in the organization, to be directly under the Radiological Safety Officer. This reorganization simplified operational procedures by centralizing control of the Radiological Safety Support Unit and by placing the commanding

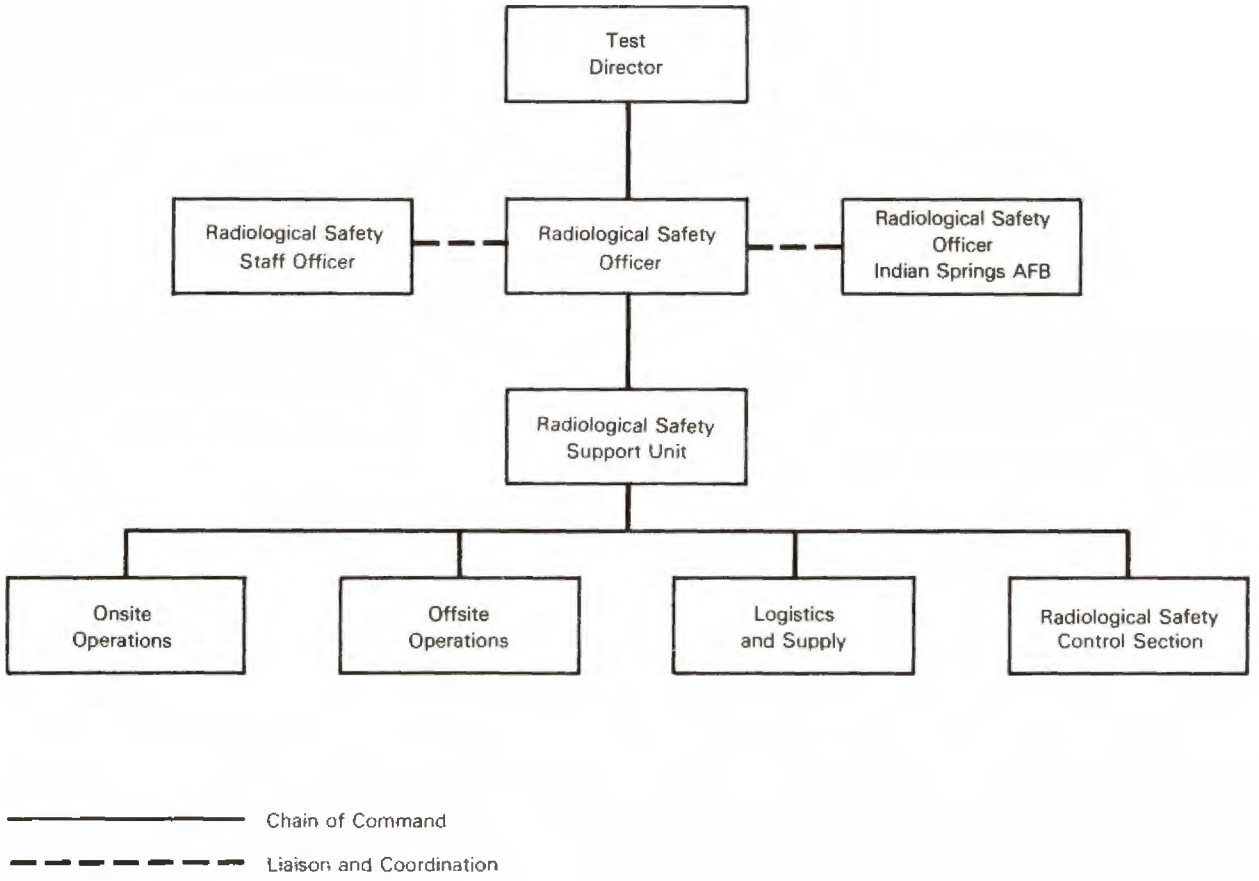

Figure 5-2: INITIAL RADIOLOGICAL SAFETY UNIT

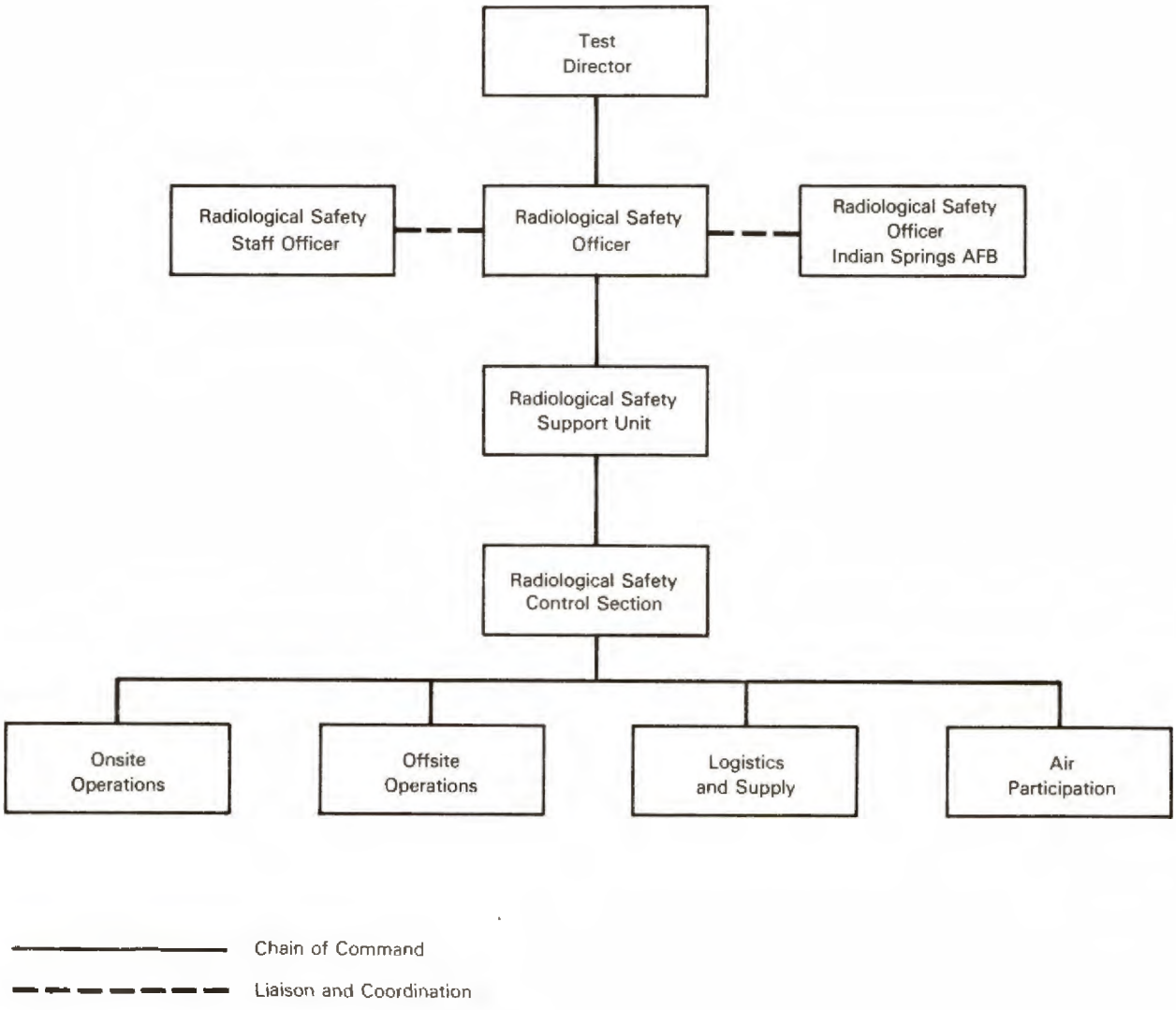

Figure 5-3: RADIOLOGICAL SAFETY UNIT AFTER SHOT NANCY

officer of the Radiological Safety Support Unit in direct supervision of most of his assigned personnel (70; 74).

The Radiological Safety Officer was directly accountable to the Test Director. The Radiological Safety Officer coordinated all radiological safety activities of JTO and informed the Test Director of radiological conditions in and around the NPG. In addition, he coordinated radiation protection activities with the Indian Springs AFB Radiological Safety Officer (74).

The Radiological Safety Staff Officer worked closely with the Radiological Safety Officer and the Test Director. The Radiological Safety Staff Officer advised the Test Director on the radiological safety of aircraft crews, sample-handling personnel, and aircraft decontamination crews at Indian Springs AFB, on general medical matters, and on all radiological safety matters affecting personnel within 320 kilometers of the NPG (74).

The Control Section Officer maintained maps and charts showing the current onsite and offsite radiological conditions, as well as weather and air data. He also supervised the preparation of fallout prediction maps before each shot. The Control Officer was responsible for knowing the location of all work parties and survey groups; he coordinated their locations by working with the Onsite Operations Officer. Finally, the Control Officer plotted data received from the Air Participation Unit, AFSWC. These data allowed him to discuss, with representatives of the Civil Aeronautics Administration and the Test Director's office, the return to normal airway traffic (74).

The Onsite Operations Section, under the direction of the Onsite Operations Officer, was responsible for (74; 87):

- Providing project monitors
- Briefing monitors and project personnel

- Conducting initial surveys
- Controlling access into contaminated areas
- Maintaining onsite radiological situation maps
- Decontaminating personnel
- Decontaminating vehicles and equipment
- Issuing and processing film badges
- Maintaining exposure records.

The Offsite Operations Officer was responsible for the radiological safety of all personnel within a 320-kilometer radius of the NPG. The Offsite Operations Officer accordingly maintained offsite radiological situation maps, requested low-altitude aircraft surveys to obtain data for these maps, measured the airborne and surface concentration of radioactivity in various areas, and determined the pattern of fallout (70; 74).

The Logistics and Supply Officer was responsible for (74):

- Dispatching and controlling all vehicles used by the Radiological Safety Support Unit
- Issuing, processing, and maintaining records of equipment and supplies required to support activities of the Radiological Safety Support Unit.

The Air Liaison Officer, a pilot with a radiological safety background, administered the Air Participation Unit and was responsible for obtaining weather reconnaissance, cloud-tracking, and aerial survey data from the appropriate AFSWC or Air Weather Service aircraft. These data were furnished to the Control Officer as an aid to determining when airways should be closed or reopened to regular traffic operations and to help in establishing the direction and extent of fallout (74).

5.2.2 Onsite Operations

The Onsite Operations Section was composed of four subordinate sections:

- Dosimetry and Records
- Monitoring
- Plotting and Briefing
- Decontamination.

Together with the Onsite Operations Office, members of these subsections were responsible for all onsite radiological safety activities.

The Onsite Operations Section was staffed by four officers, who coordinated and supervised the activities of all four subsections. Specifically, the officers were responsible for (74):

- Maintaining a daily schedule of operations
- Establishing checkpoints to control access to contaminated areas
- Issuing "Area Access Clearance" forms to groups entering any area with radiation levels greater than 0.01 R/h
- Publishing a weekly listing of all personnel who had accumulated exposures greater than 2.0 roentgens
- Notifying the Radiological Safety Officer and project director concerning all personnel who exceeded the 3.9 roentgen exposure limit
- Furnishing personnel as needed to assist in the operation of the Control Section
- Maintaining journals describing preparation of reports of operations.

Dosimetry and Records

The Dosimetry and Records Section was composed of three officers and 16 enlisted men. This section provided each

individual going into a radiologically controlled area* with a combination of DuPont Type 502 and 606 film badges and one or more self-reading pocket dosimeters. The film packet consisted of DuPont type 502 and 606 film with a range of 0.0002 to 300 roentgens. Pocket dosimeters were available in ranges of 0.0 to 0.2 roentgens, 0.0 to 1.0 roentgen, 0.0 to 10.0 roentgens, and 0.0 to 50 roentgens (74).

The Onsite Operations Office determined daily requirements for film badges and pocket dosimeters for the groups taking part in the tests. A dosimetry clerk recorded the name, rank, service number (if appropriate), organization, and project affiliation of each participant in the group. He entered the data onto Form R101, the Daily Record of Radiation Exposure, shown in figure 5-4. This form, filled out in duplicate, matched film badge number and pocket dosimeter size and serial number to the name of each individual using the devices (74).

The dosimetry clerk issued the duplicate copy of Form R101, together with the film badges and pocket dosimeters, to the monitor accompanying the party, or to the party leader if a monitor was not required. The Dosimetry and Records Section retained the original copy of Form R101 pending return of the dosimeters. Upon completion of the mission, the monitor or party leader collected the dosimeters and returned them and the copy of Form R101 to the clerk at the Dosimetry and Records Section. Individuals who had lost either film badges or pocket dosimeters filled out Form R111, shown in figure 5-5, explaining the reason for the loss. Upon receiving and processing pocket dosimeters, members of the Dosimetry and Records Section immediately recorded the readings on Form R101. The section calibrated pocket dosimeters monthly (74).

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*A radiologically controlled area was one with radiation intensities exceeding 0.01 R/h.

DAILY RECORD OF RADIATION EXPOSURE

Date:

Group: Series:

	NAME (LAST, FIRST, MIDDLE INITIAL) RANK, FILE NUMBER OR ASN ORGANIZATION PROJECT	FILM BADGE NUMBER	POCKET DOSIMETER SIZE & NUMBER	FILM BADGE		POCKET DOSIMETER
				DENSITY	MR	

Control Film No.________ Received: ________ Film Badges Issued By________ Time:________

Standard Film No.________ ________ Pocket Dosimeters Returned: ________ Time:________

____
(Signature)

Remarks:

Figure 5-4: FORM R101, DAILY RECORD OF RADIATION EXPOSURE USED BY THE ONSITE OPERATIONS OFFICE

PRIVACY ACT MATERIAL REMOVED
BEST AVAILABLE COPY

Form R111

CERTIFICATION OF LOST DOSAGE DEVICE

DATE _____

I the undersigned certify that the (film badge)(dosimeter) No._____
(strike out one)

issued to me on _____ for the purpose of determining the radiation dosage received
(date of issue)

by me, was lost in Area _____ between the hours of _____ and _____

while working on Project Number _____.

FOR LOST FILM BADGE ONLY: I realize that I will be credited with the same radiation dosage as received by that member of my party who received the highest radiation dosage during this mission.

SIGNED: _____
(First Name, Middle Initial, Last Name)

_____
(Grade, if applicable, and ID No.)

_____
(Home Organization)

Figure 5-5: FORM R111, DESCRIPTION OF CIRCUMSTANCES UNDER WHICH FILM BADGE OR POCKET DOSIMETER WAS LOST

Film badges were forwarded along with Form R101 to the film badge processing laboratory in the Radiological Safety Building at the Control Point. After developing the films, members of the Dosimetry Section determined the net optical density or darkness of the films with a densitometer. By comparing to a standard calibration curve and a densitometer, dosimetry personnel then determined the radiation exposures indicated by the various film densities. Both the density readings and the exposure readings were entered on Form R101, after which the films were placed in small envelopes and filed alphabetically by name (74).

The Dosimetry and Records Section also maintained Form 102R, Individual Accumulative Radiation Exposure Record, shown in figure 5-6, as a permanent record of cumulative individual exposure. At the completion of the daily dosimeter processing, members of the Dosimetry and Records Section transferred information from Form R101 to Form 102R. They sent cumulative exposure records for each individual in the Onsite Monitoring Section to the Onsite Operations Office, the Monitoring Section, and the Radiological Safety Officer. Additionally, the Dosimetry and Records Section prepared a report three days after each shot listing individuals who had accumulated more than 2.0 roentgens of gamma radiation exposure. The Radiological Safety Officer received a copy of this report, which listed individuals alphabetically and by project (1; 74).

At the conclusion of Operation UPSHOT-KNOTHOLE, the Dosimetry and Records Section compiled the records of individual cumulative exposures into a report. Copies of the report were forwarded to the Director, AEC Division of Biology and Medicine, and to the AFSWP surgeon. Military installations and home offices of civilians assigned to the operation received the appropriate portions of that report (1b; 74). In addition, exposed film badges worn by DOD personnel were forwarded along with Forms 102R to the AFSWP surgeon at the conclusion of

Operation UPSHOT-KNOTHOLE. The Test Director received the film badges and Forms 102R for non-DOD personnel (74).

FORM 102R INDIVIDUAL ACCUMULATIVE RADIATION EXPOSURE RECORD

DATE		FILM BADGE					DOSIMETER		REMARKS
19_____	Number	Density		Milliroentgens			(mr)		
		W	S	W	S	Cum	Day	Cum	

NAME: (Last, First, Middle Initial) RANK: ASN: HOME ORG:

Figure 5-6: FORM 102R, THE ONSITE OPERATIONS OFFICE PERMANENT RECORD OF INDIVIDUAL CUMULATIVE RADIATION EXPOSURE

Monitoring

The Monitoring Section, composed of 16 officers and 91 enlisted men, performed the daily monitoring assignments required by the Onsite Operations Officer. These assignments included (74):

- Conducting ground surveys of shot areas
- Posting signs warning of contaminated areas
- Operating checkpoints
- Accompanying program and project personnel into areas with radiation intensities greater than 0.1 R/h

- Operating the personnel decontamination station
- Furnishing monitors for the fixed vehicle decontamination station.

Monitors conducted initial ground surveys after each detonation, beginning from several minutes to almost an hour following shot-time. The initial survey party, consisting of four or five two-man teams, traveled in radio-equipped vehicles to the shot area, where they took radiation intensity readings along stake lines. Other members of the onsite group, probably Plotting and Briefing personnel, had laid out these stake lines in 45-degree radials from ground zero. Monitoring teams moved along the stake lines toward ground zero, taking radiation intensity readings as they went, as indicated in figure 5-1. The monitors radioed information on the radiation intensity, location, and time to the Plotting and Briefing Section, which then drew radiation isointensity contour maps. The monitoring teams, who proceeded no farther than the 10.0 R/h area, customarily resurveyed the shot area in the days after the shot (70; 74; 88). Variations of these procedures are described in the monitoring sections of the UPSHOT-KNOTHOLE single-shot and multi-shot volumes.

The sign-posting detail, consisting of one officer and four enlisted men, posted signs and placed road barricades in radiation areas, as directed by the Onsite Operations Officer. Members of the detail placed signs daily on barricades delineating the 0.01 R/h areas on all main and secondary access roads. This detail was also responsible for posting signs around the 0.1 R/h isointensity area (74).

Checkpoint monitors ensured that each party entering a controlled area had a properly authorized area access clearance, Form R110. This form, shown in figure 5-7, was issued by the Onsite Operations Office. The checkpoint monitors made sure that

the composition of the party and its protective equipment agreed with the entries on Form R110. If the form was completed correctly, the monitor noted the time of entry in the document and returned it to the party proceeding into the forward area. When the party returned to the checkpoint, the monitor filled in the exit time and submitted the form on that day to the Onsite Operations Office, which filed the document (74).

Form R110

AREA ACCESS CLEARANCE

DATE:_____ CHECK POINT:_____
Project No._____ Time of Entry:_____
Foreman:_____ Checked in by:_____
Monitor:_____ Time of Exit:_____
No. in the Party:_____ Checked out by:_____
Briefed by:_____
Protective Clothing and Equipment Required:

☐ Protective Clothing ☐ Film Badges/man ☐ G-M Survey Meter ☐ Other (Specify)

☐ Respirators ☐ Pocket Dosimeter Range:___ No._____ ☐ I-C Survey Meter _____ _____

Cleared for entry at_____ hours to Area_____ Recommended Time of Stay_____

REMARKS: (See Reverse Side) BY:_____
(Signature)

Figure 5-7: AREA ACCESS CLEARANCE FORM

In addition to processing Form R110, the checkpoint monitors surveyed personnel and equipment leaving the test area with TIB survey meters. When radiation intensities exceeded 0.001 R/h for personnel and 0.007 R/h for vehicles and equipment, the checkpoint monitors provided the party with brooms to sweep dust from themselves and the equipment. The purpose of this preliminary

decontamination was to prevent a possible accumulation of contaminated dust on project participants and near the Radiological Safety Building at the Control Point (74).

The Onsite Operations Office assigned monitors to accompany parties into areas with radiation intensities exceeding 0.1 R/h. The monitors then filled out an area access clearance form. These monitors acted in an advisory capacity only, keeping the recovery party leader informed of radiation intensities at all times (74).

Vehicle monitors operated in conjunction with the decontamination unit, both in the fixed decontamination station near the Radiological Safety Building and in any mobile vehicle decontamination stations established in the field. To clear vehicles for return to Camp Mercury, monitors measured radiation intensities with the MX-5 survey instrument. Vehicles had to register less than 0.007 R/h of gamma radiation close to any outside surface, or less than 0.007 R/h of beta plus gamma radiation on any inside surface (74).

Plotting and Briefing

The Plotting and Briefing Section, which consisted of two officers and two enlisted men, plotted radiological situation maps based upon information provided by survey parties. They worked in the Briefing Room of the Radiological Safety Building, where they developed maps showing the location of 0.01, 0.1, 1.0, and 10.0 R/h isointensity areas. They updated these maps daily, or as often as resurveys were conducted. The Radiological Safety Control Officer received up-to-date copies of the radiation situation maps. In addition, a member of this section posted a copy of the current map on Building 200, in the quonset area of Camp Mercury, so that personnel were aware of the radiological environment in the test area (74).

A member of the Plotting and Briefing Section briefed the leader and monitor of each party before that party entered a radiation area. The briefing included an explanation of the radiological situation in the area, the location of checkpoints, and the radiological safety regulations for radiation areas. After completing his presentation, the person who gave the briefing signed the area access clearance form for the party and gave the form to the party monitor or leader (74).

Decontamination

The Decontamination Section, consisting of two officers and eight enlisted men, was responsible for decontaminating personnel, vehicles, and equipment used in contaminated areas. In addition to their decontamination duties, all section personnel were available for assignment as monitors (74).

A minimum of six personnel, four with monitoring duties, operated the Personnel Decontamination Station. One individual, stationed outside the entrance, directed all individuals to remove tape, booties, and gloves, in that order, and to put them in designated receptacles. All gloves and booties were considered contaminated and were not monitored. Next, two persons with MX-5 portable survey instruments surveyed personnel in the checkroom. When measured about five centimeters from the surface, outer garments and equipment with radiation levels in excess of 0.007 R/h of gamma, or undergarments and external respirator surfaces with levels in excess of 0.002 R/h of beta and gamma, were turned in to a member of the Supply Section. After this check, personnel took showers. One monitor was stationed at the exit of the shower to check skin contamination. Personnel with radiation intensities in excess of 0.002 R/h returned to the showers (74).

All vehicles and equipment leaving the test area were stopped at the checkpoints and monitored for contamination.

Vehicles and equipment registering less than 1,000 counts per minute of alpha contamination per 55 square centimeters, less than 0.007 R/h of gamma outside, and less than 0.007 R/h of gamma plus beta inside, passed through the checkpoints. All vehicles and equipment exceeding these radiation levels were sent to the decontamination station in the Control Point Area (74).

Decontamination procedures consisted of washing the contaminated item with steam and hot soapy water and then placing it on a ramp to drain. The washwater was allowed to drain into the ground. After washing, personnel monitored the vehicle or equipment to determine whether the decontamination was successful. If the radiation intensities had not been reduced to those specified above, the washing and monitoring procedure was repeated. When contamination could not be reduced, even after five or six washings, the vehicle or equipment was placed in a "hot park" adjacent to the decontamination building until radioactivity decayed to an acceptable level. Vehicles or equipment could not be removed without approval of the Decontamination Section Officer. Personnel periodically monitored vehicles and equipment in the hot park, and when the radiation intensities had decayed to less than 0.007 R/h, the vehicles and equipment were available for return to service (74).

The Decontamination Section kept records indicating the type and number of vehicles and equipment decontaminated. To ensure that all contaminated vehicles and equipment had been decontaminated, section personnel compared their records with those kept at the checkpoints in the forward test areas (74).

5.2.3 Offsite Operations

The Offsite Operations Section, which involved monitors, radio operators, laboratory personnel, and administrators, was responsible for radiological safety within a 320-kilometer radius

of the NPG. This unit engaged 38 monitors, 11 of whom were military personnel. The other monitors were LASL and Public Health Service personnel (74).

The Offsite Operations Section operated a series of fixed stations to collect data to use in preparing radiological situation maps. The stations also received information from the cloud tracking and aerial survey aircraft. They determined the airborne and surface concentration of radioactivity, the particle size distribution, and the decay rate of fission products. With these data, the section assessed the offsite radiation exposure potential associated with the nuclear detonations (74).

5.2.4 Logistics and Supply

The mission of the Logistics and Supply Section was to furnish the Radiological Safety Support Unit with supplies, equipment, transportation, and communications. This section was divided into the following groups (74):

- Logistics and Supply
- Unit Supply and Laundry
- Instrument Issue and Repair
- Motor Maintenance.

The Logistics and Supply Group consisted of an officer and two enlisted men. The officer developed equipment purchase requests, procured military and civilian motor transport as required, and maintained contact with the Radiological Safety Officer and with AFSWP, AEC, and REECo supply officers. The allocation of all equipment and supplies was recorded in a daily journal (74).

The two other members of the Logistics and Supply Group issued protective equipment and clothing from the first floor of the Radiological Safety Building, providing 24-hour service.

Protective clothing and equipment, such as shoe covers, overalls, caps, gloves, and respirators, were issued with a hand receipt for five-day periods. Members of this office also maintained records of available equipment (74).

The Unit Supply and Laundry Group, made up of an officer and 12 enlisted men, issued supplies other than specific radiological safety equipment, on a daily basis. Laundry personnel, who worked on the south side of the Radiological Safety Building, washed coveralls, caps, booties, and gloves turned in by the Personnel Decontamination Station. They transferred the laundered items to supply for reissue after monitoring. Respirators were disassembled, washed, disinfected with alcohol, and reassembled with new filters before reissue (74).

The Instrument Issue and Repair Group was staffed by four enlisted men from the Signal Corps. This section, located in the basement of the Radiological Safety Building, operated only on shot-days. Section personnel issued beta and gamma radiation detecting instruments and maintained a ready supply of portable alpha counters. Clerks issued the instruments for seven-day periods, after which replacements were issued as necessary. The returned instruments were repaired and calibrated as needed (74).

The Motor Maintenance Group, consisting of one officer and four mechanics, was part of the DOD motorpool at Camp Mercury. Members of this section maintained military vehicles that were used for radiological safety activities. The AEC motorpool was responsible for civilian vehicles. Motor Maintenance personnel kept a daily record of all military radiological safety vehicles dispatched and returned (74).

5.2.5 Air Participation

Air participation in radiation protection activities involved two types of missions: cloud tracking and aerial surveys (74). Cloud tracking was conducted from B-25 and B-29 aircraft to determine the path of the cloud resulting from the detonation and to aid in the decisions to close and to reopen commercial airways. Aerial surveys were conducted from L-20 and C-47 aircraft, flying at low altitudes, to determine the fallout contamination pattern after each shot. AFSWC provided the crews and aircraft for these surveys (74). The general procedures for cloud tracking and terrain surveys are detailed in section 4.4.

5.2.6 Control Section

The Control Section coordinated all radiological safety data for presentation to the Test Director, the Radiological Safety Officer, and other interested parties. The Control Officer, who was a radiological safety engineer, was responsible for obtaining and posting data to reflect both the onsite and the offsite radiological conditions (74).

The Control Section displayed maps showing the onsite radiological conditions in the shot area and in the general test area. The map of the individual shot area showed in detail the position of the 0.01, 0.1, 1.0, and 10.0 R/h isointensity lines, as indicated by the latest radiation survey. On shot-day, section personnel posted radiological data on this map as the reports of the survey teams were received. On subsequent days, they placed acetate sheets over the map with the isointensity lines drawn from data obtained during the resurveys. The map of the general test area showed isointensity lines and individual readings at specific stations of interest. Both maps reflected the latest available radiation survey data (74).

Cloud-tracking data were plotted and displayed on a map in the control room. In this manner, the location and altitude of the cloud were monitored. Data obtained from the aerial survey aircraft were also posted on a map in the control room. These data were converted to ground-level readings, and isointensity lines were drawn to delineate the fallout pattern. The path of the aerial survey aircraft was determined using the latest information on winds at shot-time. These routes were communicated when possible to Air Operations Center at least one hour before takeoff (74).

In addition to displaying the onsite data, the Control Section showed offsite survey data by means of a map and a status chart. The map reflected the fallout reports of offsite monitors, and the chart showed successive readings at points of interest in the predicted and actual fallout areas. The offsite data were also posted on the aerial survey map to show the correlation between the air and ground readings (74).

5.3 RADIATION PROTECTION PLANS FOR THE AIR FORCE SPECIAL WEAPONS CENTER

During Operation UPSHOT-KNOTHOLE, AFSWC performed a variety of tasks in support of the test groups and the Test Manager: airdrop missions, cloud sampling, cloud tracking, aerial surveys, sample courier missions, and security sweeps.

The radiological safety of air and ground personnel involved in AFSWC test and support operations was a command responsibility. Part of this responsibility was to insure compliance with safety regulations published by the Test Director. Included in these regulations was the maximum permissible radiation exposure limit for Operation UPSHOT-KNOTHOLE: No individual could receive more than 3.9 roentgens of gamma radiation during the entire operation unless otherwise specified by proper authorities. The

exposure limit for AFSWC members was the same as for other JTO participants (71-74).

During a December 1952 meeting, AFSWC, AEC, and LASL personnel discussed the radiation exposure that cloud-sampling pilots could receive at each shot. They calculated that these pilots, in conducting required missions, were likely to accumulate 5.8 roentgens of exposure during the series. The planning personnel decided, therefore, that two groups of pilots were necessary for the sampling program so that none of them would exceed the 3.9 roentgen limit (71).

5.3.1 Organization and Responsibilities

In January 1953, AFSWC agreed to assume a number of tasks related to radiological safety, as it had done in previous test series. These responsibilities included:

- Providing trained personnel for all ground and air monitoring duties
- Providing film badges, dosimeters, and monitoring equipment
- Operating decontamination areas for personnel, aircraft, and equipment.

Although the 4925th Test Group (Atomic) had overall responsibility for AFSWC radiological protection, two units had the responsibility of implementing AFSWC radiological safety procedures: the 4935th Air Base Squadron at Indian Springs AFB and the 4901st Support Wing (Atomic) at Kirtland AFB (71).

While the 4901st Support Wing (Atomic) was in charge of radiological safety activities at Kirtland AFB, the Base Radiological Warfare Defense Unit of the 4910th Air Base Group actually performed the operations. Included in these activities were preshot briefings, airborne and ground monitoring associated

with missions staged from Kirtland AFB, and aircraft decontamination. The 4901st provided a C-47 aircraft and crew for radiological aerial surveys. Based at Kirtland, this C-47 was assigned to the 4935th throughout UPSHOT-KNOTHOLE (71).

At Indian Springs AFB, the 4935th Air Base Squadron performed radiation protection activities, with the aid of augmentation personnel from the 4901st Support Wing (Atomic) and the 4926th Test Squadron. The 4935th issued radiological protection equipment, which had been supplied by the 4901st, to personnel stationed at the base. The 4926th sample-removal crew removed particulate cloud samples from sampler aircraft, while 4926th radiological safety personnel monitored and decontaminated the aircraft (71).

Operation UPSHOT-KNOTHOLE was the first nuclear weapons testing series in which the 4935th participated. Before July 1952, the 4901st had performed all the radiological safety procedures at Indian Springs AFB. After that time, however, the 4935th Air Base Squadron was organized to conduct support activities at the base (71).

5.3.2 Briefing

Before each mission, ground and air crews at Kirtland and Indian Springs AFB attended briefings on the weather, the mission, and precautions to minimize exposures to radiation while performing the mission. At Kirtland AFB, the 4901st Support Wing (Atomic) presented this information, while at Indian Springs, the Operations Unit Number One (Test) (Provisional), part of the 4925th Test Group (Atomic), conducted the briefings. These briefings were usually given the day before each shot. At the time of the briefings, crews received film badges and pocket dosimeters, and the sampler control aircrew received high-density goggles (71).

5.3.3 Protective Equipment and Personnel Dosimetry

The primary requirement of the AFSWC radiation protection program was to minimize exposure of AFSWC personnel to radiation. Because exposure to ionizing radiation may be both internal or external, AFSWC developed procedures to minimize both types of exposure.

To minimize internal exposure, AFSWC personnel wore respirators when they worked in enclosed spaces or in activities producing airborne contamination, such as the unloading of particulate samples. Aircrews were on full oxygen. For pressurized aircraft, a filter installed on the air intake system collected 99 percent of the radioactive particles one micron or larger in size.

To minimize external exposure, participants wore protective clothing over their regulation clothing while in contaminated areas. Upon leaving contaminated areas, personnel removed this protective clothing to reduce the potential for spreading contamination to other areas. During sampling missions, pilots wore lead-glass vests, which reduced radiation exposure by 17 percent. While vests covering the sides and front of the torso were first tested at NANCY, they were not available for all sampler pilots until Shot BADGER (105). Other procedures for limiting the radiation exposure of pilots are discussed in section 4.4.

5.3.4 Monitoring and Decontamination

Portable radiation detection instruments were used to measure radioactive contamination on personnel and aircraft at both Kirtland AFB and Indian Springs AFB. The assessment of contamination levels was an important step in establishing restricted areas and in determining whether protective procedures had been successful. To prevent the spread of contamination, and

thus reduce personal exposure to radiation, AFSWC developed special contamination control procedures for aircrews, ground crews, and aircraft.

Personnel

Ground personnel planning to enter contaminated areas obtained anticontamination clothing, film badges, and dosimeters from the Personnel Decontamination Section. Individuals with open breaks in their skin could not enter contaminated areas unless the breaks were covered. The cuffs of the coveralls were closed with masking tape. Upon leaving the contaminated areas, personnel were monitored. If, after removing their anticontamination clothing, they registered radiation intensities greater than 0.007 R/h of gamma radiation, they were decontaminated at the Personnel Decontamination Station (105).

Aircraft

A special pad was built at Indian Springs AFB for the decontamination of aircraft. The pad was located off an old taxi strip and was in an isolated area about 900 meters east of the regular aircraft parking ramp. The surface of the concrete pad was sealed to minimize penetration of the contaminated water into the concrete. Base water was piped to the decontamination pad. An underground drain carried the wash water away from the pad and into a leach field in the desert. This leach field, as well as the decontamination pad, was marked with appropriate warning signs, when required. The aircraft were towed to and from the decontamination pad (105).

After landing, aircraft taxied to designated areas where they were met by radiological personnel who unloaded the cloud samples (if any) and assisted in removing the crew. The crew went to the Personnel Decontamination Station for monitoring and decontamination. The aircraft were then monitored to determine levels of radioactive contamination. If gamma intensities

exceeding 0.007 R/h were found, the aircraft were towed to the decontamination pad. Aircraft were decontaminated by repeated washings with detergent and water or were parked in designated areas, marked with radiation signs, and quarantined until radiation decayed (94). Sampler F-84s, however, could not be decontaminated to the 0.007 R/h limit. At the conclusion of UPSHOT-KNOTHOLE, after flying several missions, the aircraft had residual contamination in the 0.050 to 0.150 R/h range. This resulted primarily from particles impacting the compressor blades of the engine (105).

Radiation monitors were present during all phases of decontamination, and decontamination crew members wore anti-contamination clothing, film badges, and pocket dosimeters.

CHAPTER 6

DOSIMETRY FOR DEPARTMENT OF DEFENSE PERSONNEL AT OPERATION UPSHOT-KNOTHOLE

This chapter summarizes the data available as of 1982 regarding the radiation doses received by Department of Defense personnel during their participation in various military and scientific activities during Operation UPSHOT-KNOTHOLE. It is based on research that identified the participants, their unit of assignment, and their doses.

6.1 PARTICIPATION DATA

The identity of participants was determined from several sources:

- Final Report of Operations, Exercise Desert Rock V, provided information on unit participation and activities of Desert Rock organizations (120).
- Weapons Test Reports for AFSWP and other scientific projects often identified participating personnel, units, and organizations.
- After-action reports, security rosters, and vehicle loading rosters related to the military exercises identified some participants.
- Morning reports, unit diaries, and muster rolls identified personnel assigned to participating units, absent from their home unit, or in transit for the purpose of participating in a nuclear weapons test.
- Official travel or reassignment orders provided information on the identity of transient or assigned personnel participating in the nuclear weapons tests.
- Discharge records, maintained by all services, aided in identification.

- The Final Exposure Report for Operation UPSHOT-KNOTHOLE supplied information on the names, units, and total gamma doses for JTO participants (1b).
- The services' Reserve Personnel Officer provided information on participants still carried on active or inactive reserve rolls.
- A widely publicized national call-in campaign sponsored by the Department of Defense identified some of the test participants.

6.2 DOSIMETRY DATA

Most of the dosimetry data for Operation UPSHOT-KNOTHOLE were derived from film badge records. If film badge data were not available, however, radiation doses could be calculated if sufficient information were available concerning personnel activities, the radiological environment, and the time that personnel spent in that environment.

6.2.1 Film Badge Data

During Operation UPSHOT-KNOTHOLE, the film badge was the primary device used to measure the radiation dose received by individual participants. Individual JTO and Desert Rock participants were issued a film badge for Shots ANNIE and NANCY. At Shot BADGER, the Marines participating in the troop maneuver received two badges per platoon. For the remaining shots, Desert Rock troops who performed similar duties were issued one badge per platoon (120). The film badge, normally worn at chest level on the outside of clothing, was designed to measure the wearer's exposure to gamma radiation from external sources. The film badges were insensitive to neutron radiation and did not measure the amount of radioactive material that might have been inhaled or ingested.

Both the Joint Test Organization and Exercise Desert Rock V had their own radiological safety personnel who issued, received, processed, and interpreted film badges during Operation UPSHOT-KNOTHOLE. The Desert Rock V film badge program was administered by the 505th Signal Service Group (Composite Company), while the JTO and AFSWC badge program was administered by the Dosimetry and Records Section of the Radiological Safety Support Unit. Both Desert Rock and JTO radiological safety personnel used manual clerical procedures to record film badge data. As described in chapter 5, JTO radiological safety personnel used Forms R101 and 102R, while Desert Rock personnel used a file card to record cumulative personnel film badge data (74; 120).

At the conclusion of Operation UPSHOT-KNOTHOLE, it was the intent of the services to send individual dose records to each participant's home station for inclusion in his personnel records. When the individual left the service, his records were retired to a Federal records repository (84-85).

The film badge data summarized in this chapter were obtained from the following sources:

- Historical files of the Reynolds Electrical and Engineering Company (REECo) - REECo has been the prime support contractor to the Department of Energy and previously to the AEC Nevada Operations Office at the Nevada Test Site since 1952. REECo assumed responsibility for onsite radiological safety in July 1955 and subsequently collected available dosimetry records for nuclear test participants at all nuclear testing operations from 1945 to the present. REECo has on microfilm all available exposure records for individuals at Operation UPSHOT-KNOTHOLE, consisting primarily of those participants working under the JTO.

- Military medical records, maintained at the National Personnel Records Center, St. Louis, Missouri, for troops separated from military service, or at the Veterans Administration, for individuals who have filed for disability compensation or health benefits. Unfortunately, many records were destroyed in a fire at the St. Louis repository in July 1973.

That fire destroyed 13 to 17 million Army records for personnel discharged between 1 November 1912 and 31 December 1959, and for members of the Army Air Corps/Air Force discharged between 31 December 1947 and 31 December 1963.

- Final Exposure Report of the Radiological Safety Support Unit, which contains the names, units, and cumulative gamma doses for JTO participants (1b).

- Radiological Safety Report for Operation UPSHOT-KNOTHOLE, which provides some aggregate information on the number of JTO participants who accumulated gamma exposures for specific events of the UPSHOT-KNOTHOLE Series (74).

- Final Report of Operations for Exercise Desert Rock V, Operations, which includes aggregate dose data for Desert Rock participants (120).

- Messages from Camp Desert Rock to Sixth Army Headquarters regarding average estimated exposures for Desert Rock troops and observers at each shot (129-134).

- Cumulative Radiological Listings (Forms 102R), which provide film badge readings for many participants at Operation UPSHOT-KNOTHOLE (1a).

6.2.2 Reconstructed Dose Data

In certain instances when film badge data were missing for large groups of personnel that might have been exposed, DOD conducted research to calculate radiation doses resulting from external exposure to gamma radiation. When it was apparent that DOD personnel might have been exposed to significant neutron radiation and/or airborne radioactive material, doses from these sources were also calculated. Based on reconstructions of the troop activities and the radiological environment, these calculations consider the following (106):

- Weapon characteristics (yield, height of burst, and design)

- Residual radiation survey data

- Personnel activities
  - Distance from burst and shielding
  - Time, positions, and activities in radiation areas.

6.3 DOSIMETRY DATA FOR OPERATION UPSHOT-KNOTHOLE PARTICIPANTS

This section presents data on the doses that DOD participants received during Operation UPSHOT-KNOTHOLE. Beginning with a presentation of external gamma radiation doses organized by unit, service, and activity, the section proceeds to discuss the circumstances surrounding specific instances of overexposure. Finally, the section discusses doses that have been reconstructed for Desert Rock participants.

6.3.1 External Gamma Exposure Data

Tables 6-1 through 6-6 present the gamma exposure data available from film badge records for DOD participants at Operation UPSHOT-KNOTHOLE.* The tables indicate the following by service or unit:

- The number of personnel identified by name
- The number of personnel identified by both name and film badge
- The average gamma exposure in roentgens
- The distribution of these exposures.

As indicated in table 6-1, only 54 percent of the estimated 21,000 DOD participants were identified by name and about 10 percent by name and film badge reading.

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*All tables are located at the end of this chapter.

Table 6-1 summarizes all exposures for each service. In addition to the Army, Navy, Marine Corps, and Air Force designations, the table includes data for scientific personnel, contractors, and affiliates and participants whose service affiliation is unknown. Tables 6-2 through 6-6 provide information about the gamma exposures received by the various participants. In these tables, distributions and averages are given by unit. For a unit to be represented in the table, it must meet at least one of the following criteria:

- Records are available for ten or more individuals from the unit
- At least one individual in the unit had a gamma exposure of 1.0 roentgen or more.

Units not meeting these criteria are consolidated in table 6-2 through 6-6 in the "other" category, and a distribution of cumulative exposures with an average is provided for them. Tables 6-2a through 6-6a list the individual units that comprise the "other" category (13; 79).

6.3.2 Instances of Gamma Exposure Exceeding Prescribed Limits

The prescribed limits of gamma radiation exposure were 6.0 roentgens for Desert Rock V participants and 3.9 roentgens for JTO and AFSWC personnel. An exception to these limits was made for the volunteer officer observer program. After discussion with OCAFF and careful review, the AEC Test Manager approved a special limit of 10.0 roentgens of gamma radiation for each shot for the volunteer officer observers at Desert Rock V, with a total exercise limit of 25 roentgens. Despite this exception, the standard policy for both Exercise Desert Rock V and JTO was to minimize individual exposures, while still allowing participants to accomplish the operational requirements of each activity or mission (70; 74; 120; 196-197; 239).

Table 6-7 is a list of the units of JTO personnel who received gamma radiation exposures in excess of the 3.9 roentgen limit. In addition to the unit name, the table lists the number of personnel whose doses exceeded the limit and the individual doses they received (1b; 74; 79; 106; 120). The activities in which these personnel may have participated are described below.

Several of the overexposed personnel entered radiation areas to retrieve instruments and experimental data. Those participants were from the following organizations:

- Armed Forces Special Weapons Project
- Allied Research Associates
- Naval Medical Research Institute
- Army 1090th Reporting Group
- Bureau of Ships
- Lookout Mountain Laboratory
- Evans Signal Laboratory
- Naval Research Laboratory
- Wright Air Development Center
- University of California, Los Angeles
- Naval Ordnance Test Center.

These personnel entered the area at recovery hour or when radiological safety personnel allowed them through the checkpoints. Recovery teams were usually accompanied by radiological safety personnel and always traveled by vehicle. Factors that could have contributed to overexposure of some project personnel during critical recovery operations included higher than anticipated radiation levels, difficulty in maneuvering vehicles over rough terrain or unforeseen obstacles, and longer time spent in radiation areas while searching for equipment (1b; 2-12; 33-43; 79).

Personnel from Fort McClellan, Alabama, made up most of the Radiological Safety Support Unit. This unit also included

radiation monitors from other Army stations, as well as individuals from the Navy and Air Force. Radiological safety monitors from this unit accompanied AFSWP project personnel on many of the recovery missions. In addition, Radiological Safety Support Unit personnel surveyed the shot area after each detonation and manned the checkpoints to the radiation areas. Because they repeated their activities during several shots, members of the Radiological Safety Support Unit spent more time in or near radiation areas than other personnel (74).

Two Air Force personnel from Kirtland AFB and one from the 4925th Test Group received exposures in excess of the 3.9 roentgen limit (1b; 79). Personnel from Kirtland AFB supported the various AFSWC operations at UPSHOT-KNOTHOLE. The 4925th Test Group was the principal unit performing cloud sampling. Apparently, other Air Force units were involved with operational support activities. These units probably included Keesler, Lowry, and Bergstrom AFB (105; 229):

Research indicates that only three Marines received exposures that exceeded the 6.0 roentgen Desert Rock limit. Two were from the 1st Battalion, 8th Marines, and one from the 1st Provisional Guided Missile Battalion (79; 120).

Activities have not been documented for the remaining individuals listed in table 6-7. The individuals included representatives from the Bureau of Medicine and Surgery, Commander Amphibious Group 3, Commander Task Group 7.3, Naval Hospital, Naval Air Station (Coronado, California), Naval Training Center, Naval Supply Center, Wichita Municipal Airport, Walker AFB, Wright Patterson AFB, Ballistic Research Laboratories, and Marine Corps School, as well as those in Desert Rock and the unknown categories.

Exposures of the volunteer officer observers are treated separately because of the special circumstances surrounding these exposures. Seven of the eight Desert Rock V volunteer officer observers at Shot SIMON received exposures exceeding the 10.0 roentgen limit. The average gamma exposures from film badge readings for the volunteer officer observers at Shots BADGER and SIMON are included in table 6-8, along with the reconstructed average gamma dose for the volunteer officer observers at Shot NANCY. One volunteer officer observer witnessed Shots NANCY, BADGER, and SIMON and had a total gamma exposure for the three shots of 26.6 roentgens (239; 241).

6.3.3 Reconstructed Doses

Film badge data were not available for most of the Exercise Desert Rock V maneuver troops and observers. However, the external gamma and neutron doses for the observers have been calculated. These calculations were based on the activities performed by the observers, which included witnessing the shot and touring the equipment display areas before and after the shot (106).

Observers representing each of the armed services participated in most of the UPSHOT-KNOTHOLE shots. They consisted of the following personnel:

- Army personnel who were assigned to Camp Desert Rock as the permanent support party
- A few civilians from various Army agencies
- Service observers from the various military services who were sent to Camp Desert Rock to witness a specific shot or shots to become familiar with the effects of nuclear detonations
- Officers who volunteered to witness one or more of Shots NANCY, BADGER, and SIMON.

Because the service observers had first priority for observing the shots, it appears that only a few support personnel from Camp Desert Rock participated as observers in more than one shot (106; 120; 196).

Reconstructed dose data are available for Desert Rock observers at UPSHOT-KNOTHOLE. Observers were present at all shots except RUTH and CLIMAX. The volunteer officer observers participated only at NANCY, BADGER, and SIMON. The reconstructed radiation doses of Desert Rock V observers are shown in table 6-8. The reconstructions are based on the radiological environment encountered by the observers and the time spent in this environment. Gamma doses include possible initial radiation from the observed shot, as well as residual radiation from the observed test and earlier tests. Table 6-8 also presents the calculated neutron doses for the observers. Gamma and neutron doses are listed separately to facilitate comparison with existing film badge data, which indicate gamma dose only (106).

The parameters used to reconstruct doses for observers at Shot ANNIE are typical of those used for each of the shots listed in table 6-8. At ANNIE, 535 Desert Rock observers witnessed the shot from trenches located 3,200 meters south-southwest of ground zero. After the blast wave from the detonation had passed, the observers stood in the trenches to witness the rising fireball. About 25 minutes later, they began the tour of the equipment display area located south of ground zero. They spent about 40 minutes in the display area and went as far as the 2.5 R/h line, which was the limit of their advance. They then returned to the trench area and, at approximately 0800 hours, were picked up by trucks for the return trip to Camp Desert Rock. By relating these activities to the radiological environment (initial and residual radiation), a dose was calculated for the group of observers. Based upon the data presented above, dose reconstruction indicates that the ANNIE observers received 0.52 roentgens gamma dose and 0.018 roentgens neutron dose (106).

Table 6-1: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR OPERATION UPSHOT-KNOTHOLE PARTICIPANTS BY AFFILIATION

Service	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (Roentgens)	Gamma Exposure (Roentgens)				
				<.1	.1-1.0	1.0-3.0	3.0-5.0	5.0+
Army	7,445	469	1.555	163	113	73	101	19
Navy	504	348	1.161	125	106	74	25	18
Marine Corps	2,286	144	2.174	41	10	31	52	10
Air Force	757	757	0.654	399	233	71	33	21
Scientific Personnel, Contractors, and Affiliates	222	222	0.638	96	79	42	2	3
Service Unknown*	63	63	0.644	31	15	14	3	0
TOTAL	11,277	2,003	1.061	855	556	305	216	71

*Film badge data are available, but service affiliation is not.

Table 6-2: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR ARMY PERSONNEL AND AFFILIATES, OPERATION UPSHOT-KNOTHOLE

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (Roentgens)	Gamma Exposure (Roentgens)				
				< .1	.1-1.0	1.0-3.0	3.0-5.0	5.0+
Aberdeen Proving Ground, Aberdeen, MD	20	20	0.670	3	12	5	0	0
Ballistic Research Laboratories	4	4	5.290	0	0	0	3	1
Battalion Combat Team (XI) (Provisional), Armored Company, Fort Campbell, KY	171	0						
Camp Carson, CO	110	0						
Camp Desert Rock V	4,420	12	0.732	5	6	0	0	1
Camp Desert Rock V, Infantry Company "A"	139	0						
Camp Desert Rock V, Infantry Company "B"	123	0						
Chemical Corps (sic)*	11	0						
Engineer Research and Development Laboratories	2	2	1.350	0	1	1	0	0
Engineer School, Fort Belvoir, VA	13	10	1.240	3	2	5	0	0
Evans Signal Laboratory	3	3	11.170	0	1	0	0	2
Fort Bragg, NC	2	2	1.322	1	0	1	0	0
Fort Eustis, VA	6	5	0.551	1	3	1	0	0
Fort Jackson, SC	49	0						
Fort Lee, VA	4	4	1.077	2	0	2	0	0
Fort Monmouth, NJ	10	10	0.149	8	2	0	0	0
Headquarters, Air Materiel Command, Dayton, OH	2	2	0.655	1	0	1	0	0
Observers	13	0						
Office Chief Army Field Forces	18	0						
Quartermaster Research and Development Agency	4	4	1.145	0	1	3	0	0
Radiation Safety, Fort McClellan, AL	202	202	2.430	29	45	32	82	14
Radiation Safety Monitors	90	90	0.857	58	8	11	13	0
Signal Corps	13	3	1.578	1	0	2	0	0
Signal Corps Pictorial Unit, Long Island, NY	7	2	0.998	1	0	1	0	0
Tradcom (sic)	1	1	1.490	0	0	1	0	0
Walter Reed Army Medical Center	7	7	0.990	2	3	1	1	0
First Army, Battalion Combat Team (Provisional)	183	0						
Sixth Army	34	1	3.270	0	0	0	1	0
1st Armored Division, Fort Hood, TX	38	0						
1st Guided Missile Group, (Provisional)	19	0						

* "Sic" indicates that the units and/or home stations appear in this table as they were entered in the source documentation.

Table 6-2: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR ARMY PERSONNEL AND AFFILIATES, OPERATION UPSHOT-KNOTHOLE (Continued)

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (Roentgens)	Gamma Exposure (Roentgens)				
				< .1	.1-1.0	1.0-3.0	3.0-5.0	5.0+
3rd Armored Cavalry Regiment	80	0						
19th Engineer Combat Battalion, Company "B", Fort Meade, MD	12	0						
31st Infantry (Dixie) Division, (National Guard Unit) Camp Atterbury, IN	31	0						
50th Chemical Platoon (Service)	12	0						
82nd Airborne Division, 505th Airborne Infantry Regiment	93	0						
278th Regimental Combat Team	46	0						
412th Engineer Construction Battalion	66	0						
505th Military Police, Camp Desert Rock Detachment	19	0						
508th Airborne Regimental Combat Team	16	0						
1090th Reporting Group Army	39	39	0.562	20	13	4	1	1
3623rd Direct Support Ordnance Company	13	0						
9771st Technical Service Unit, Military Police Detachment	1	1	2.050	0	0	1	0	0
Other**	1,062	44	0.192	28	16	0	0	0
Unit Unknown***	237	1	1.430	0	0	1	0	0
TOTAL	7,445	469	1.555	163	113	73	101	19

** For list of units in this category, see table 6-2a.
*** Unit information is unavailable.

Table 6-2a: DETAILED LISTING OF "OTHER" CATEGORY, ARMY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE

NUMBERED UNITS

First Army, 108th Counterintelligence Corps Detachment
Second Army, Fort Meade, MD
Third Army, Fort McPherson, GA
Fourth Army, Fort Sam Houston, TX
Fifth Army, Chicago, IL

III Corps, Fort MacArthur, CA
XVIII Airborne Corps, Headquarters, Fort Bragg, NC

1st Battalion Combat Team (XI) (Provisional), Fort Monroe, VA
1st Infantry Company, Battalion Combat Team, (X3) (Provisional)
1st Infantry Division [Wuerzburg, Germany]
1st Mobile Army Surgical Hospital
1st Provisional Detachment, Fort Hood, TX (sic)*
1st Special Troop Battalion, Company "A", GA (sic)
1st Transportation Battalion (sic)
2nd Armored Cavalry Regiment [Nuremberg, Germany]
2nd Artillery Group (SUP GP) (sic)
2nd Engineer Battalion [Korea]
2nd Infantry Company, Battalion Combat Team, Provisional (sic)
2nd Infantry Group (sic)
3rd Battalion, 1st Battalion, Company "B" (sic)
3rd Battalion, 2nd Student Regiment, Headquarters (sic)
3rd Infantry Division [Korea]
5th Armored Division, Fort Chaffee, AR
5th Infantry Division, 11th Regiment, Indiantown Gap, PA
5th Quartermaster Battalion, Company "C", Fort Chaffee, AR

6th Armored Division, Headquarters Company
6th Infantry Division, 1st Infantry Regiment, Fort Ord, CA
6th Infantry Division, 20th Infantry Regiment, Ford Ord, CA
6th Transportation Company (Helicopter) [Korea]
7th Armored Division, Camp Roberts, CA
7th Armored Division, 48th Armored Infantry Battalion, Company "A", Camp Roberts, CA
7th Engineer Combat Battalion, Indiantown Gap, PA
7th Infantry Division (Training) [Korea]
8th Antiaircraft Artillery Battalion, Camp Lucas, MI
8th Infantry Division, 13th Infantry Regiment, Fort Jackson, SC
8th Infantry Division, 61st Infantry Regiment, Fort Jackson, SC
9th Antiaircraft Artillery Battalion, Fort Winfield Scott, CA
9th Infantry Division, Fort Dix, NJ
9th Infantry Division, 39th Infantry Regiment, Fort Dix, NJ

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*"Sic" indicates that units and/or home stations appear in this table as they were entered in the source documentation.

Table 6-2a: DETAILED LISTING OF "OTHER" CATEGORY, ARMY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE (Continued)

9th Medical Battalion, Company "B", Fort Dix, NJ
9th Ordnance Battalion, (Special Weapons Support), Sandia Base, NM
9th Reconnaissance Battalion (sic) [9th Reconnaissance Company Fort Dix, NJ]

10th Infantry Division, 25th Field Artillery Battalion, Fort Riley, KS
10th Infantry Division, 86th Infantry Regiment, Company "H"
10th Medium Tank Battalion, Company "A"
11th Airborne Division, 88th Antiaircraft Battalion
11th Airborne Division, 503rd Airborne Infantry Regiment Fort Campbell, KY
11th Airborne Division, 505th Airborne Infantry Regiment, Fort Campbell, KY
11th Airborne Division, 511th Airborne Infantry Regiment
11th Armored Cavalry Regiment, Fort Carson, CO
13th Antiaircraft Artillery Gun Battalion, Battery "B"
14th Antiaircraft Artillery Battalion, Battery "A"
15th Ordnance Battalion, Special Weapons (sic)

16th Base Post Office
16th Combat Engineers, Fort Hood, TX
16th Signal Battalion, Camp San Luis Obispo, CA
17th Field Artillery Group, Fort Sill, OK
18th Antiaircraft Artillery Gun Battalion, Detroit, MI
19th Antiaircraft Artillery Group, Fort Meade, MD

21st Engineer Battalion, Camp Carson, CO
21st Field Artillery Battalion, Indiantown Gap, PA
22nd Engineer (sic)
22nd Armored Field Artillery Battalion, Fort Hood, TX
24th Chemical Decontamination Company, Fort Knox, KY
24th Evacuation Field Hospital, Fort Benning, GA
25th Signal Battalion, Fort Devens, MA

26th Transportation Battalion, 23rd Truck Company
26th Transportation Battalion, 31st Truck Company
27th Field Artillery, Fort Hood, TX
28th Antiaircraft Artillery Headquarters, Selfridge Air Force Base, MI
28th Antiaircraft Artillery Regiment, 504th Antiaircraft Artillery Battalion, Battery "C"
28th Field Artillery Battalion, Battery "C"
28th Infantry Regiment, BCT, Fort Jackson, SC
28th Infantry Division, COB, NGU, PA (sic)

30th Antiaircraft Artillery Group, Fort Berry, CA
30th Infantry Regiment, Fort Benning, GA

Table 6-2a: DETAILED LISTING OF "OTHER" CATEGORY, ARMY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE (Continued)

30th Infantry Regiment, Company "I", Fort Benning, GA
30th Infantry, 2nd Battalion, Headquarters Company
30th Regimental Combat Team
30th Tank Battalion, Fort Knox, KY
31st Signal Company, Camp Atterbury, IN
33rd Infantry Regiment (sic)
34th Chemical Company, Fort McClellan, AL
34th Engineer Combat Company, Headquarters, Camp Roberts, CA
34th Quartermaster Battalion, 591st POL Depot Company
35th Antiaircraft Artillery Gun Battalion
35th Field Artillery Battalion, Battery "A", Fort Riley, KA
35th Infantry Regiment, Headquarters Company [Korea]

37th Division, 147th Infantry Regiment, Company "L"
37th Infantry Division, Camp Polk, LA
37th Infantry Division, 145th Regiment
Headquarters, National Guard Unit
37th Quartermaster Company
38th Antiaircraft Artillery Brigade

40th Antiaircraft (sic) [Battalion] [Biebrich, Germany]
41st Field Artillery Battalion
44th Infantry Division, Fort Lewis, WA
44th Ohio National Guard Division (sic) [Illinois National Guard Division, Fort Lewis, WA]
45th Antiaircraft Artillery Battalion
45th Brigade, Fort Sheridan, IL
45th Medium Tank Battalion, Fort Knox, KY
45th Transportation Truck Company

47th Engineer Camouflage Battalion, Fort Riley, KS (sic)
47th Infantry Division, 164th Infantry Regiment, Headquarters and Headquarters Company, Fort Rucker, AL
47th Infantry Division, 135th Infantry Regiment, 1st Battalion (Vikings), Company "C" [National Guard Unit, MN]
47th Infantry Regiment, 2nd Battalion, Fort Dix, NJ
47th Reconnaissance Company TDY, Fort Rucker, AL
48th Engineer Topographic Battalion
49th Field Artillery Battalion, Fort Benning, GA
49th Depot Maintenance Company, Fort Belvoir, VA

52nd Artillery Brigade
52nd Field Artillery Group
52nd Ordnance Battalion, Fort Bragg, NC
53rd Transportation Truck Company
54th Medical Group, Fort Benning, GA
55th Field Artillery (sic)

Table 6-2a: DETAILED LISTING OF "OTHER" CATEGORY, ARMY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE (Continued)

56th Antiaircraft Artillery Gun Battalion, Fort Monroe, VA
56th Light Truck Company, Camp Pickett, VA
59th Antiaircraft Artillery Battalion (A/W)(SP), Fort Bliss, TX

60th Field Artillery Regiment, Headquarters Battery
61st Engineer Construction Battalion, Camp Polk, LA
61st Ordnance Group, Fort Hood, TX (sic)
62nd Chemical, Smoke Generator Company, Fort McClellan, AL
65th Infantry Regiment [Puerto Rico]

66th Signal Battalion, Company "A", Fort Bragg, NC
68th Armored Field Artillery Battalion, Fort Hood, TX
68th Engineer Combat Group, 3rd Engineer Battalion
69th Infantry Division, Company "H"

70th Engineer Construction Company [attached, 9th Infantry Division], Fort Dix, NJ
71st Antiaircraft Gun Battalion
73rd Armored Field Artillery Battalion, Battery C, Fort Hood, TX
74th Signal Company
75th Antiaircraft Artillery Battery

76th Field Artillery Battery, Fort Riley, KS
76th Field Artillery Tr., Fort Knox, KY (sic)
77th Antiaircraft Artillery Gun Battalion, Fort MacArthur, CA (sic)
77th Brigade, Headquarters Abbott (sic)
78th Infantry Co "E" (sic)

81st Reconnaissance Battalion, Company D, Fort Hood, TX
82nd Airborne Division, 504th Airborne Infantry Regiment, Fort Bragg, NC
82nd Airborne Division, 307th Engineer Combat Battalion, Company "A"
82nd Airborne Division, 325th Airborne Regiment, Supply Company
82nd Field Artillery Battalion, Headquarters Battery, Fort Ord, CA
85th Infantry Regiment, Company "C", Fort Riley, KS

87th Infantry Regiment, Fort Riley, KS (sic)
87th Transportation Truck Company
89th Field Artillery, Fort Campbell, KY

90th Gun Battalion (sic)
91st Engineer Combat Battalion, Camp Roberts, CA
93rd Army Band, Camp Irwin, CA
94th Veterinary Food Inspection Service Detachment
95th Engineers Battalion, Headquarters Company, Camp Roberts, CA

Table 6-2a: DETAILED LISTING OF "OTHER" CATEGORY, ARMY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE (Continued)

97th Field Artillery, 40 Artillery Group, Camp Carson, CO
99th Antiaircraft Artillery Gun Battalion

104th Antiaircraft Artillery, Headquarters Company, Camp Atterbury, IN
114th Field Artillery, Headquarters Battery
115th Light Truck Company, Fort Meade, MD
115th Ordnance POL Company

126th Trucking (sic)

131st Tank Battalion, Company "A", Fort Knox, KY
135th Ordnance Ballistic and Technical Service Detachment, Aberdeen Proving Ground, MD

136th Field Artillery Battalion, Fort Polk, LA
146th Explosive Disposal Squad, Fort Banks, MA
158th Infantry Regiment, 2nd Battalion, Headquarters Company [AZ National Guard]
164th Ordnance Company Comp (sic)
168th Infantry Division (sic)
174th Military Police Battalion (sic)
187th Field Artillery Battalion (Observation), Fort Sill, OK
188th Airborne Infantry Regiment, Fort Campbell, KY
191st Field Artillery Battalion, Camp Drum, NY
194th Tank Battalion, Headquarters Company, Camp Rucker, AL
198th Field Artillery Battalion, Battery "B", Fort Benning, GA
199th Antiaircraft Artillery (sic)
199th Engineer Construction Battalion, Fort Leonard Wood, MD

200th Armored Field Artillery Battalion, Camp Polk, LA
200th Heavy Motor, IN (sic)
208th Military Police Company, Fort Leonard Wood, MD
226th Military Police Company, Camp Atterbury, IN
232nd Signal Support Company, Camp Gordon, GA
259th Missile Battalion, Fort Bliss, TX
264th Field Artillery, Fort Sill, OK
265th Artillery Battalion, 29th Ordnance Company
271st Combat Engineers (sic)

303rd Signal Battalion, Company "A", Camp San Luis Obispo, CA
312th Engineer (sic)
313th Signal Battalion, Fort Meade, MD
315th Truck Division, Fort Meade, MD (sic), [115th Light Truck Company, Fort Meade, MD]
320th Airborne Field Artillery Battalion, Fort Benning, GA
338th Military Intelligence Service Battalion, Fort Meade, MD
352nd Bomb Squadron, Barksdale AFB, LA
369th Engineer Amphibious Support Regiment
378th Ordnance Company, Camp Irwin, CA
385th Chemical Decontamination Unit (sic)

Table 6-2a: DETAILED LISTING OF "OTHER" CATEGORY, ARMY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE (Continued)

403rd Evacuation Hospital, Camp Pickett, VA
406th Engineer Brigade, Fort Bragg, NC
425th Engineer Battalion (sic)
428th Antiaircraft Artillery Bat (sic)
433rd Army Band, Camp Irwin, CA
447th Antiaircraft Battalion (sic)
449th Antiaircraft Artillery Battalion, Battery "C" Fort Bragg, NC
449th Field Artillery Battalion (Observation), Headquarters Battery, Fort Bragg, NC
449th Field Artillery Battalion, Battery "B" Fort Campbell, KY (sic)
449th Field Artillery, Battery "A" (sic)
459th Antiaircraft Artillery Gun Battalion, Battery "B" Fort Barry, CA
459th Antiaircraft Artillery
466th Antiaircraft Artillery Battalion, Battery, March AFB, CA
484th Engineer Construction Battalion, Fort Knox, KY

501st Quartermaster Battalion, Fort Hood, TX
502nd Traffic Regulating Group, Fort Eustis, VA
504th Signal Base Maintenance Company, Detachment Sacramento, CA
504th Signal Service Battalion, San Luis Obispo, CA
505th Signal Construction Company, Headquarters, Alaska Communications Center
506th Helicopter Company, Fort Benning, GA
507th Armored Combat Team (sic)
509th Helicopter Company, Fort Bragg, NC
516th Antiaircraft Artillery Battalion, Detroit, MI
524th Quartermaster POL Depot Company, Lathrop, CA

528th Reclamation and Classification Company, Fort Knox, KY
531st Antiaircraft Artillery Battalion, Fort Bliss, TX
534th Reclamation and Maintenance Company (sic)
534th Signal Company, Fort Benning, GA
536th Infantry Battalion, Fort Knox, KY
537th Field Artillery Battalion, Camp Carson, CO
538th Field Artillery Battalion, Camp Carson, CO
544th Airborne Field Artillery Battalion, Fort Campbell, KY
547th Field Artillery Battalion, Headquarters and Headquarters Battery, Camp Carson, CO
548th Antiaircraft Battalion, Detroit, MI
549th Quartermaster Company, New Cumberland, MD

550th Artillery Gun Battalion, Battery "A"
550th Tank Company, Fort Benning, GA
554th Antiaircraft Artillery Gun Battalion, Camp Stewart, GA
562nd Transportation Detachment [Heidelberg, Germany]
564th Artillery Unit (sic)

Table 6-2a: DETAILED LISTING OF "OTHER" CATEGORY, ARMY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE (Continued)

583rd Field Artillery Battalion, Fort Bragg, NC
594th Quartermaster Depot Company, New Cumberland, MD
598th Field Artillery Battalion, Fort Polk, LA

601st Antiaircraft Artillery Battalion, Washington, D.C.
602nd Antiaircraft Artillery Battalion, Baltimore, MD
602nd D.A.S.U. (sic)
612th Quartermaster Company, Fort Bragg, NC
613th Artillery (sic)
663rd Field Artillery Battalion, Battery B, Fort Bragg, NC
669th Truck Company, Fort Riley, KS
687th Artillery Battalion (Observation) (sic)
695th Field Artillery Battalion Battery "B", Fort Knox, KY

701st Armored Infantry Battalion, Company "C", Fort Hood, TX
702nd Ordnance Company (sic)
702nd Transportation Company, Fort Eustis, VA
709th Military Police Battalion [Frankfurt, Germany]
710th Tank Battalion, Fort Campbell, KY
718th Antiaircraft Artillery Gun Battalion, Fort Baker, CA
718th Transportation Company, Fort Bliss, TX
721st Military Police (sic)
728th Antiaircraft Artillery, 718th Antiaircraft Artillery Gun Battalion (sic)
740th Antiaircraft Artillery Gun Battalion, Fort Baker, CA
752nd Antiaircraft Gun Battalion, Oakland, CA
758th Field Artillery Battalion, Fort Bragg, NC

832nd Ordnance Company, Fort Knox, KY
836th Ordnance Depot Company, Fort Bragg, NC
847th Field Artillery Battalion, Battery "B", Camp Carson, CO
867th Field Artillery Battalion, Fort Sill, OK
868th Field Artillery Battalion, Battery "C", Fort Bragg, NC

916th Medical Company, Camp Pickett, VA
969th Engineer Construction Battalion, Fort Belvoir, VA
973rd Engineer Construction Battalion, Camp Carson, CO
977th Radiation Co (sic)
981st Engineer Construction Battalion, Fort Bragg, NC
988th Antiaircraft Battalion (sic)
998th Engineer Construction Battalion [Toul, France]

1019th Transportation Base Depot
1402nd Engineer Combat Battalion [Karlsruhe, Germany]

2307th Engineer Aviation Battalion 7 AF Co (sic)

3040th Area Service Unit, Station Medical (sic)
3422nd Area Service Unit, Fort Bragg, NC
3441st Area Service Unit, Fort Gordon, GA

Table 6-2a: DETAILED LISTING OF "OTHER" CATEGORY, ARMY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE (Continued)

4005th Medical Detachment, Fort Hood, TX
4009th Area Service Unit, Fort Polk, LA
4052nd, 1st Composite Group, Area Service Unit, Fort Bliss, TX
4054th Area Service Unit, Fort Bliss, TX

5012th Area Service Unit, Fort Sheridan, IL
5015th Area Service Unit, Reception Center, Camp Atterbury, IN
5017th Area Service Unit, Headquarters Detachment, Fort Leonard Wood, MO (sic)
5028th Area Service Unit, Camp Lucas, MI
5043rd Area Service Unit, Fort Riley, KS
5050th Antiaircraft Artillery Battalion, Headquarters Battery (sic)

5102nd ASU Illinois Reserves, Chicago, IL
5103rd Area Service Unit, Fort Benjamin Harrison, IN
5422nd Area Service Unit, Fort Sheridan, IL
7001st Area Service Unit, Military District of Washington, D.C.
7131st Area Service Unit, Communications Detachment

8017th Area Service Unit, Fort Leonard Wood, MD
8450th Headquarters and Headquarters Service Company, Sandia Base, NM
8452nd Administrative Area Unit, Headquarters, Sandia Base, NM
8462nd Administrative Area Unit [Special Weapons Headquarters, Kileen Base, TX]
8601st Administrative Area Unit, Vint Hill, Warrenton, VA

9301st Technical Service Unit, Detachment 2, Aberdeen Ordnance Depot, MD
9393rd Technical Service Unit, White Sands Proving Ground, NM
9710th Technical Service Unit, Detachment 4, Edgewood, MD
9940th Technical Service Unit, Fort Sam Houston, TX

Department of the Army

Adjutant General's Office
Army General Staff
DCCMLO DA HQ (sic)
Office, Assistant Chief of Staff, Operations
Office, Assistant Chief of Staff, Intelligence
Office, Assistant Chief of Staff, Logistics
Office, Chief Chemical Corps
Office, Chief Legislative Liaison
Office, Chief of Finance
Office, Chief of Engineers
Office, Chief of Psychological Warfare
Office, Chief of Radiological Warfare Division
Office, Chief of Staff
Office, Chief of Transportation

Table 6-2a: DETAILED LISTING OF "OTHER" CATEGORY, ARMY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE (Continued)

Office, Chief Ordnance Board
Office, Chief Signal Officer
Office of Information
Provost Marshal General's Office
Quartermaster General's Office

Commands

Headquarters, U.S. Army Pacific
Western Area Antiaircraft Command

Schools and Training Centers

AAA RTC (sic)
Antiaircraft and Artillery School
Antiaircraft and Guided Missile School, Fort Bliss, TX
Armored Combat Training Center
(The) Armored School, Fort Knox, KY
Army Medical Service Graduate School
Artillery Center, Fort Sill, OK
(The) Artillery School, Fort Sill, OK
Brooke Army Medical Center, Fort Sam Houston, TX
Command and General Staff College, Fort Leavenworth, KS
Antiaircraft and Guided Missile Branch, The Artillery School, Fort Bliss, TX
(The) Infantry School, Fort Benning, GA
Leadership School, Camp/Fort Chaffee, AR
Medical Field Services School, Fort Sam Houston, TX
Ordnance Guided Missile School, Redstone Arsenal, Huntsville, AL
Provost Marshal General's School, Camp Gordon, GA
Psychological Warfare School, Fort Bragg, NC
Transportation Center, Fort Lee, VA
Transportation School, Fort Eustis, VA
U.S. Military Academy, West Point, NY

Locations

Camp Cook, CA
Camp Drum, NY
Camp Gordon, GA
Camp Kilmer, NJ
Camp Pickett, VA
Camp Polk, LA
Camp Roberts, CA
Carlisle Barracks, PA
Dugway Proving Ground, UT
Fort Belvoir, VA
Fort Benning, GA
Fort Bliss, TX
Fort Campbell, KY

Table 6-2a: DETAILED LISTING OF "OTHER" CATEGORY, ARMY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE (Continued)

Fort Dix, NJ
Fort Harrison, IN
Fort Hood, TX
Fort Jay, NY
Fort Knox, KY
Fort Leavenworth, KS
Fort Lee, VA
Fort Leonard Wood, MD
Fort Lewis, WA
Fort Mason, CA
Fort Meade, MD
Fort Ord, CA
Fort Rucker, AL
Fort Sam Houston, TX
Fort Sill, OK
Fort Story, VA
Indiantown Gap, Annville, PA
Sandia Base, NM
White Sands Proving Ground, NM

Miscellaneous

Arizona Military District
Arlington Hall Station, Arlington, VA
Armed Forces Special Weapons Project
Army Chemical Center, Edgewood, MD
Army Communications and Administration Center (sic)
Army Env Health Lab (sic)
Army Field Forces, Board 2, Fort Knox, KY
Army Field Forces, Board 4, Fort Bliss, TX
Army Security Agency
Atomic Test Unit (sic)
Attached to 7th Fleet (sic)
Civil Defense Director (sic)
Corps of Engineers
DD4 M.P. Unit (sic)
Directorate of Weapons Effects Tests, Sandia Base, NM
Engineer Development Board, Fort Belvoir, VA
Field Command, Armed Forces Special Weapons Project, NV
Headquarters, Military District of Maryland, Baltimore, MD
Headquarters, Military District of Washington
Joint Task Force 7
Lookout Mountain Laboratory, Hollywood, CA
Nevada Proving Ground, NV
Ordnance Corps, Picatinny Arsenal, NJ
Quartermaster Depot, Jeffersonville (sic)
Transportation Research and Development Board, Fort Eustis, VA
University of California
U.S. Army Hospital, Fort Jackson, SC
U.S. Army Rehabilitation Center (sic)

Table 6-2a: DETAILED LISTING OF "OTHER" CATEGORY, ARMY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE (Continued)

U.S. Coast and Geological Survey, Washington, D.C.
Valley Forge Army Hospital
Waterways Experiment Station, Vicksburg, MS

Table 6-3: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR NAVY PERSONNEL AND AFFILIATES, OPERATION UPSHOT-KNOTHOLE

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (Roentgens)	Gamma Exposure (Roentgens)				
				<.1	.1-1.0	1.0-3.0	3.0-5.0	5.0+
Aberdeen Proving Ground	1	1	1.885	0	0	1	0	0
Armed Forces Special Weapons Project	12	10	1.613	4	5	0	0	1
Ballistic Research Laboratories, Aberdeen, MD	6	6	1.030	1	2	3	0	0
Bureau of Medicine	2	2	7.328	0	0	0	0	2
Bureau of Ships	9	9	1.062	3	2	3	1	0
Bureau of Supply and Accounts	6	6	2.122	0	1	4	1	0
Bureau of Yards and Docks	7	7	0.369	4	2	1	0	0
Civil Effects Test Group	15	15	1.036	2	6	7	0	0
Commandant, Eleventh Naval District	10	10	1.405	0	4	6	0	0
Commander Amphibious Group 3	1	1	6.040	0	0	0	0	1
Commander Joint Task Force 7	1	1	3.110	0	0	0	1	0
Commander Task Group 7.3	3	3	4.668	0	0	1	1	1
Directorate, Weapons Effects Test	19	19	0.964	6	6	6	1	0
Edgerton, Germeshausen and Grier, Inc.	1	1	1.800	0	0	1	0	0
Long Beach Naval Shipyard	1	1	2.565	0	0	1	0	0
Los Alamos Scientific Laboratory	5	4	0.445	1	2	1	0	0
Mare Island Naval Shipyard	1	1	2.225	0	0	1	0	0
Naval Air Station, Norfolk, VA	1	1	1.055	0	0	1	0	0
Naval Air Station, Olathe, KS	1	1	1.165	0	0	1	0	0
Naval Air Station, Sandia, NM	25	1	0.130	0	1	0	0	0
Naval Amphibious Base, Coronado, CA	5	5	1.653	1	3	0	0	1
Naval Attachment, Kirtland AFB, NM	12	12	0.430	3	8	1	0	0
Naval Auxiliary Air Station, Mustin Field	20	20	0.073	15	5	0	0	0
Naval Electronics Laboratory	14	14	0.551	2	7	5	0	0
Naval Hospital, San Diego, CA	1	1	5.860	0	0	0	0	1
Naval Medical Research Institute	16	16	4.627	0	2	0	7	7
Naval Ordnance Laboratory	27	20	0.536	9	7	3	1	0

Table 6-3: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR NAVY PERSONNEL AND AFFILIATES, OPERATION UPSHOT-KNOTHOLE (Continued)

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (Roentgens)	Gamma Exposure (Roentgens)				
				<.1	.1-1.0	1.0-3.0	3.0-5.0	5.0+
Naval Ordnance Test Center, CA	83	43	0.220	38	4	0	0	1
Naval Radiological Defense Laboratory	17	15	0.990	4	6	5	0	0
Naval Research Laboratory	27	25	1.502	4	6	12	3	0
Naval Supply Center, Norfolk, VA	1	1	4.580	0	0	0	1	0
Naval Supply Depot, Bayonne, NJ	1	1	3.080	0	0	0	1	0
Naval Supply Depot, San Diego, CA	2	1	1.390	0	0	1	0	0
Naval Training Center, San Diego, CA	1	1	7.030	0	0	0	0	1
New York Naval Shipyard Material Laboratory	1	1	3.540	0	0	0	1	0
San Francisco Naval Shipyard	4	3	2.443	0	1	0	2	0
University of Illinois	1	1	1.560	0	0	1	0	0
2d Marine Corps Provisional Atomic Exercise Brigade	37	0						
9978th Radiological Safety Support Unit	1	1	2.050	0	0	1	0	0
Other*	46	31	0.185	21	10	0	0	0
Unit Unknown**	60	36	1.306	7	16	7	4	2
TOTAL	504	348	1.161	125	106	74	25	18

* For list of units in this category, see table 6-3a.
** Unit information is unavailable.

Table 6-3a: DETAILED LISTING OF "OTHER" CATEGORY, NAVY PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE

Atomic Energy Commission, Washington, D.C.
Air Force Special Weapons Center, Kirtland AFB, NM
Bureau of Aeronautics, Washington, D.C.
Chief of Naval Operations, Washington, D.C.
Fort McClellan, AL (sic)*
Naval Air Material Center, Philadelphia, PA
Naval Air Special Weapons Facility
Naval Air Station, Moffett, CA
Naval Air Station, North Island, CA
Naval Air Station, Point Mugu, CA
Naval Air Station, Seattle, WA
Naval Civil Engineering Laboratory, Point Hueneme, CA
Naval Hospital, Portsmouth, VA
Naval Postgraduate College, Monterey, CA
Naval Medical Laboratory, New London, CT
Navy Observers
Office of Naval Research, Washington, D.C.
USA Chemical Center (sic)
VP-5 Air Squadron (sic)
1st Marine Division
3d Marine Division

*"Sic" indicates that the units and/or home stations appear as they were entered in the source documentation.

Table 6-4: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR MARINE CORPS PARTICIPANTS AT UPSHOT-KNOTHOLE

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (Roentgens)	Gamma Exposure (Roentgens)				
				<1	.1-1.0	1.0-3.0	3.0-5.0	5.0+
Camp Pendleton, CA — Observers	5	4	1.658	0	0	4	0	0
Company C, Headquarters Battalion Washington, D.C. — Observers	25	2	0.000	2	0	0	0	0
Headquarters Company, Headquarters Battalion 3d Marine Division Fleet Marine Force Pacific	30	6	2.433	2	0	1	2	1
Headquarters, Squadron 16, Marine Air Group 16 Air Fleet Marine Force Pacific	16	0						
Headquarters; 2d Marine Corps Atomic Exercise Brigade, Camp Pendleton, CA	30	4	4.085	0	0	0	3	1
Marine Air Base Squadron 16, Marine Air Group 16 Air Fleet Marine Force Pacific	15	2	0.530	0	2	0	0	0
Marine Corps School, Quantico, VA — Observers	27	18	2.273	3	0	10	5	0
Marine Helicopter Atomic Test Unit	1	1	4.510	0	0	0	1	0
Marine Helicopter Squadron 162, Marine Air Group 16 Air Fleet Force Pacific	90	3	0.934	1	1	1	0	0
Marine Helicopter Squadron 163, Marine Air Group 16 Air Fleet Marine Force Pacific	28	3	0.033	3	0	0	0	0
Marine Helicopter Squadron 361, Marine Air Group 16 Air Fleet Marine Force Pacific	39	1	0.075	1	0	0	0	0
Marine Helicopter Squadron 362, Marine Air Group 16 Air Fleet Marine Force Pacific	37	1	0.315	0	1	0	0	0
Marine Helicopter Squadron 363, Marine Air Group 16 Air Fleet Marine Force Pacific	20	3	0.040	3	0	0	0	0
1st Battalion, 3d Marines, 3d Marine Division	24	0						
1st Battalion, 8th Marines, 2d Marine Division	869	24	2.929	3	1	7	10	3
1st Provisional Marine Corps Guided Missile Battalion, China Lake, CA — Observer	1	1	7.670	0	0	0	0	1
2d Battalion, 3d Marines, 3d Marine Division	894	44	2.962	6	1	5	28	4
Observers — Unit Unknown	97	11	1.445	3	3	2	3	0
Other*	36	14	0.007	14	0	0	0	0
Unit Unknown**	2	2	0.670	0	1	1	0	0
Total	2,286	144	2.174	41	10	31	52	10

* For list of units in this table, see table 6-4a.
** Unit information is unavailable.

Table 6-4a: DETAILED LISTING OF "OTHER" CATEGORY, MARINE CORPS PERSONNEL AND AFFILIATES, OPERATION UPSHOT-KNOTHOLE

Battery 6, 3d Battalion, 10th Marine Regiment
Battery B, 1st Antiaircraft Artillery Automatic Weapons Battalion Mobile
Battery C, 1st Antiaircraft Artillery Automatic Weapons Battalion Mobile
Headquarters and Service Company, 3d Motor Transport Battalion 3d Marine Division, Fleet Marine Force
Headquarters Battery, 16th Marine Regiment, 3d Marine Division
Headquarters Company, Headquarters Battalion, 1st Marine Division
Marine Air Base Station 16, Marine Air Group 36, 3d Marine Air Wing

2d Ordnance Battalion, 2d Marine Division, Camp Lejeune, NC
5th Marine Corps Reserve District, Arlington, VA

Observers:

- Bureau of Ordnance, Department of the Navy
- Company H, 2d Recruit Training Battalion, Parris Island, SC
- Headquarters and Service Company, 6th Marine Regiment 2d Marine Division
- Headquarters Battery 1/12, 3d Marine Division, Fleet Marine Force
- Headquarters Company, Force Troops, Fleet Marine Force Pacific
- Headquarters Company, Headquarters Battalion, Marine Corps Recruit Depot, Parris Island, SC
- Headquarters Company, Headquarters Battalion, Marine Corps Recruit Depot, San Diego, CA
- Headquarters Squadron 2, 2d Marine Air Wing, Fleet Marine Force, Marine Corps Air Station
- Headquarters Squadron 3, 3d Marine Air Wing, Fleet Marine Force, Marine Corps Air Station
- Joint Tactical Air Support Board
- Marine Corps Recruit Depot, San Diego, CA
- Service Maintenance Squadron 1, Marine Corps Air Station El Toro, CA

Table 6-5: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR AIR FORCE PERSONNEL AND AFFILIATES, OPERATION UPSHOT-KNOTHOLE

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (Roentgens)	Gamma Exposure (Roentgens)				
				<.1	.1-1.0	1.0-3.0	3.0-5.0	5.0+
Bergstrom AFB, TX	3	3	2.910	0	0	2	1	0
Brooks AFB, TX	16	16	0.684	4	8	4	0	0
Carswell AFB, TX	10	10	0.105	9	1	0	0	0
Castle AFB, CA	1	1	1.920	0	0	1	0	0
Clovis AFB, NM	2	2	0.973	0	1	1	0	0
Forbes AFB, KS	1	1	2.025	0	0	1	0	0
Headquarters, Air Research and Development Command	11	11	0.010	11	0	0	0	0
Headquarters, U.S. Air Force	16	16	0.309	12	2	2	0	0
Holloman AFB, NM	22	22	0.114	19	2	1	0	0
Keesler AFB, MS	6	6	1.571	0	3	2	1	0
Kirtland AFB, NM	194	194	0.214	136	49	6	2	1
Lackland AFB, TX	1	1	1.010	0	0	1	0	0
Lookout Mountain Laboratory, CA	42	42	0.803	20	15	2	4	1
Los Alamos Scientific Laboratory	1	1	4.610	0	0	0	1	0
Lowry AFB, CO	64	64	2.258	1	14	28	15	6
March AFB, CA	67	67	0.419	20	40	7	0	0
McGuire AFB, NJ	2	2	3.422	0	0	0	2	0
Rapid City AFB, SD	2	2	3.487	0	0	0	2	0
Walker AFB, NM	1	1	17.500	0	0	0	0	1
Westover AFB, MA	18	18	0.036	17	1	0	0	0
Wichita Municipal Airport, KS	2	2	4.635	1	0	0	0	1
Wright Air Development Center, Wright Patterson AFB, OH	21	21	3.383	3	6	2	1	9
Wright Patterson AFB, OH	1	1	6.350	0	0	0	0	1
55th Strategic Reconnaissance Squadron	40	40	0.232	11	29	0	0	0
514th Fighter Bomber Squadron	10	10	0.101	7	3	0	0	0
4901st Support Wing, Kirtland AFB, NM	8	8	0.693	4	2	2	0	0
4925th Test Group (Atomic), Kirtland AFB, NM	41	41	1.004	20	11	5	4	1
4935th Air Base Squadron, Indian Springs AFB, NV	43	43	0.170	31	9	3	0	0
Other*	111	111	0.136	73	37	1	0	0
TOTAL	757	757	0.654	399	233	71	33	21

* For list of units in this category, see table 6-5a.

Table 6-5a: DETAILED LISTING OF "OTHER" CATEGORY, AIR FORCE PARTICIPANTS, OPERATION UPSHOT-KNOTHOLE

Air Force Cambridge Research Center
Air Weather Service
Albuquerque, NM (sic)*
Bryan AFB, TX
Company "A", Infantry, Desert Rock V (sic)
Donaldson AFB, CA
Francis E. Warren AFB, WY
George AFB, CA
Godman AFB, KY
Headquarters, Air Defense Command, ENT AFB, CO
Hunter AFB, GA
Joint Task Force 132.4
Kelley AFB, TX
Langley AFB, VA
Nellis AFB, NV
Offutt AFB, NB
Patrick AFB, FL
Phillips Field AFB [Support], Aberdeen, MD
Project 23.1
Randolph Field, TX
Shaw AFB, SC
Travis AFB, CA
3rd Aircraft and Airways Communications Squadron, Mather AFB, CA
8th Air Force, Carswell AFB, TX
38th Air Division, Hunter AFB, GA
62nd Troop Carrier Wing
442nd Bombardment Squadron, Mather AFB, CA
443rd Bombardment Squadron
1090th Special Reporting Group, Sandia Base, NM
3225th Drone Squadron, Holloman AFB, NM
3381st Technical Training Squadron, Keesler AFB, MS
3540th Fighter Group (sic) [Radiological Warfare Defense Unit]
4909th Organizational Maintenance Squadron, Kirtland AFB, NM
4910th Air Base Group, Kirtland AFB, NM
6555th Guided Missile Squadron, Patrick AFB, FL

*"Sic" indicates that units and/or home stations appear in this table as they were entered in the source documentation.

Table 6-6: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR SCIENTIFIC PERSONNEL, CONTRACTORS, AND AFFILIATES, OPERATION UPSHOT-KNOTHOLE

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (Roentgens)	Gamma Exposure (Roentgens)				
				<.1	.1-1.0	1.0-3.0	3.0-5.0	5.0+
Armed Forces Special Weapons Project	5	5	0.395	2	2	1	0	0
Allied Research Association	6	6	1.491	3	1	1	0	1
Armour Research Foundation	6	6	1.499	1	1	4	0	0
Directorate of Weapons Effect Tests	128	128	0.611	58	45	22	1	2
North American Aviation	2	2	2.432	0	0	2	0	0
Odgen Transportation, UT	2	2	1.047	0	0	2	0	0
Stanford Research Institute	10	10	0.667	3	4	3	0	0
University of California, Los Angeles	16	16	0.967	6	5	4	1	0
University of Illinois	2	2	0.760	1	0	1	0	0
University of Rochester	6	6	0.589	1	4	1	0	0
Other*	37	37	0.191	21	16	0	0	0
Unit Unknown**	2	2	1.127	0	1	1	0	0
TOTAL	222	222	0.638	96	79	42	2	3

*For list of units in this category, see table 6-6a.
**Unit information is unavailable.

Table 6-6a: DETAILED LISTING OF "OTHER" CATEGORY, SCIENTIFIC PERSONNEL, CONTRACTORS, AND AFFILIATES, OPERATION UPSHOT-KNOTHOLE

APA INC (sic)*
Bendic KC Observer (sic)
Columbia University
General Dynamics/Convair Division
Department of Defense
Eastman Kodak
Federal Civil Defense Administration
Federal Services
Joint Committee on Atomic Energy Staff [Congressional Committee]
Lear Inc., Los Angeles, CA
Member of Congress
Massachusetts Institute of Technology
PBS (sic)
Scripps Institute of Oceanography
Tracer Laboratory, Inc.
University of California
University of Dayton
University of Chicago
U.S. Government (sic)

*"Sic" indicates that the table entry appears as it was entered in the source documentation.

Table 6-7: FILM BADGE READINGS EXCEEDING ESTABLISHED LIMITS FOR JTO PARTICIPANTS AT OPERATION UPSHOT-KNOTHOLE

Unit	Number of Personnel	Total Exposure (Roentgens)*
Allied Research Associates	1	6.9
Armed Forces Special Weapons Project	1	14.1
Army 1090th Reporting Group	1	5.2
Ballistic Research Laboratories	4	4.0, 4.7, 4.8, 7.7
Bergstrom Air Force Base	1	4.3
Bureau of Medicine and Surgery	2	5.8, 8.9
Bureau of Ships	1	4.2
Commander Amphibious Group 3	1	6.0
Commander Task Group 7.3	1	8.6
Desert Rock V **	1	7.1
Directorate Weapons Effects Test	3	4.4, 7.5, 7.8
Evans Signal Laboratory	2	16.1, 16.9
Fort McClellan Radiation Safety	48	3.9, 3.9, 4.0, 4.0, 4.0, 4.0, 4.0, 4.0, 4.1, 4.1, 4.1, 4.1, 4.1, 4.1, 4.1, 4.1, 4.1, 4.2, 4.2, 4.2, 4.2, 4.3, 4.3, 4.4, 4.4, 4.4, 4.4, 4.6, 4.6, 4.6, 4.7, 4.7, 4.8, 5.1, 5.3, 5.5, 5.6, 5.6, 6.5, 7.7, 7.8, 7.8, 8.4, 8.4, 8.5, 16.1, 16.8
Keesler Air Force Base	1	4.8
Kirtland Air Force Base	2	4.3, 5.1
Lookout Mountain Laboratory	3	4.5, 4.6, 8.8
Los Alamos Scientific Laboratories	1	4.6
Lowry Air Force Base, CO	7	4.4, 5.2, 5.5, 5.6, 5.7, 6.9, 8.7
Naval Amphibious Base, Coronado, CA	1	6.6
Naval Hospital, San Diego, CA	1	5.9
Naval Medical Research Institute	9	4.1, 4.4, 5.9, 6.1, 6.1, 6.5, 7.0, 7.9, 8.2
Naval Ordnance Test Center	1	7.7
Naval Research Laboratory	3	4.0, 4.4, 4.5
Naval Supply Center, Norfolk, VA	1	4.6
Naval Training Center	1	7.0
Radiological Safety Support Unit	1	3.9
University of California, Los Angeles	1	4.2
Walker Air Force Base	1	17.5
Wichita Municipal Airport	1	9.2
Wright Air Development Center	9	5.0, 5.1, 5.7, 6.9, 6.9, 7.2, 7.4, 8.1, 8.9
Wright Patterson Air Force Base	1	6.4
1st Battalion, 8th Marines**	2	6.2, 7.1
1st Provisional Marine Corps Guided Missile Battalion, China Lake, CA**	1	7.7
4925th Test Group	1	14.7
Unknown, Navy	3	4.4, 6.1, 6.4
TOTAL	119	

*Exposures rounded to nearest tenth of a roentgen.

**Subject to 6.0 Desert Rock V limit.

Table 6-8: RECONSTRUCTED DOSES FOR DESERT ROCK OBSERVERS

SHOT	CALCULATED AVERAGE GAMMA DOSE (roentgens)	AVERAGE NEUTRON DOSE (roentgens)
ANNIE	0.52	0.018
NANCY	0.35	<0.001
NANCY*	0.64	0.63
DIXIE	0	0
RAY	0	0
BADGER	1.3	<0.001
BADGER*	6.1**/7.2	2.4
SIMON	0.52	0.003
SIMON*	13.6**/13.6	28
ENCORE	0.1	<0.001
HARRY	1.3	<0.001
GRABLE	0.04	<0.001

*Volunteer officer observers

**These gamma doses are the average from actual film badge readings for the volunteer officer observers at Shots BADGER and SIMON. One volunteer officer observer witnessed all three shots and had a total exposure of 26.6 roentgens for the series (70; 239; 241).

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